STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GEOLOGY AND MINERAL DEPOSITS OF THE ANGELS CAMP AND SONORA QUADRANGLES

CALAVERAS AND TUOLUMNE COUNTIES CALIFORNIA

SPECIAL REPORT 41

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SAN FRANCISCO — SPECIAL REPORT 41 — JANUARY 1955

GEOLOGY AND MINERAL DEPOSITS OF THE ANGELS CAMP AND SONORA QUADRANGLES

CALAVERAS AND TUOLUMNE COUNTIES CALIFORNIA

By JOHN H. ERIC, ARVID A. STROMQUIST, and
C. MELVIN SWINNEY
Geological Survey, U. S. Department of the Interior

Price $3.75

GEOLOGY AND MINERAL DEPOSITS OF THE ANGELS CAMP AND SONORA QUADRANGLES CALAVERAS AND TUOLUMNE COUNTIES, CALIFORNIA*

By John H. Eric, Arvid A. Stromquist, and C. Melvin Swinney †

OUTLINE OF REPORT

Illustrations

ABSTRACT

The $7\frac{1}{2}$-minute quadrangles Angels Camp and Sonora—in Calaveras and Tuolumne Counties, California—are approximately at the geographic center of the Mother Lode gold belt. This area is underlain chiefly by steeply dipping metamorphosed sedimentary and volcanic rocks of Mesozoic and Paleozoic age, and by metamorphosed intrusive rocks of Mesozoic age. These rocks are covered in places by nearly flat-lying sedimentary and volcanic rocks of Tertiary age.

About 500 mines and prospects in the area are listed. Gold leads the minerals in value and quantity, with some 20 mines each having a recorded production of more than $200,000.

The Calaveras formation, of Paleozoic age, occurs in three belts. It is chiefly marble and schist, in part interbedded. Discontinuous strips of sheared rocks consisting

* Publication authorized by the Director, U. S. Geological Survey. Manuscript submitted for publication April 1954.

† Geologists, U. S. Geological Survey.

of tectonic breccia, marble lenses, schists, and phyllitic material have been mapped as probable Calaveras formation. These sheared rocks are confined to strongly faulted zones.

The Cosumnes formation, of Middle or Late Jurassic age, is exposed in a small part of the mapped area. This formation consists of thin-bedded tuff, slate, tuffaceous sandstone and siltstone, and chert. Overlying the Cosumnes is the Logtown Ridge formation, also of Middle or Late Jurassic age. This formation consists dominantly of rocks derived from coarse-grained, generally mafic, pyroclastics, as well as from tuff and flows. One of the most characteristic and consistent units within the Logtown Ridge formation is a green massive augite-albite-epidote greenstone derived chiefly from basalt and andesite breccia and agglomerate. The Cosumnes and Logtown Ridge formations make up the Amador group.

The youngest pre-Cretaceous sedimentary formation in the mapped area is the Mariposa slate, for which the more appropriate name Mariposa formation is proposed. This unit is of Late Jurassic age and is unconformably above the Logtown Ridge formation. The lithologic units are interbedded slate, graywacke, sandy and silty tuff, tuffaceous sandstone, and pebble conglomerate.

Part of the mapped area is underlain by phyllite and conglomerate containing stretched pebbles and part by green schist, of uncertain, pre-Cretaceous age. In general these rocks have been somewhat more metamorphosed and deformed than the rocks of known Jurassic age, and in the past most of them have been assigned to, or associated with, the Calaveras formation. Inasmuch as no valid evidence has been found for the age of these rocks, in this report they have not been assigned an age. However, in places some of them resemble rocks of the Cosumnes and Logtown Ridge formations, suggesting a possible tentative correlation with these formations.

Four formations of Tertiary age have been mapped. The oldest of these is river gravel of Eocene (?) age, containing pebbles and cobbles of pre-Tertiary bedrock. This gravel, which we believe to be approximately contemporaneous with the clay, sand, and lignite of the Ione formation farther west, is of great economic importance, for much gold has been mined from it. Unconformably overlying the river gravel is the Valley Springs formation, which consists of interbedded rhyolite tuff and gravel that contains pebbles and cobbles of bedrock. The Valley Springs formation may be of Miocene age. Unconformably overlying the Valley Springs is the Mehrten formation of Miocene and Pliocene age, a unit that is dominantly andesitic or basaltic and consists chiefly of volcanic conglomerate and mud flows, agglomerate, breccia, and tuff; the fragments are mainly of Tertiary rocks, a distinct contrast to the bedrock fragments found in the river gravel of Eocene (?) age and Valley Springs formation. Unconformably overlying the Mehrten is a latite lava flow that occupies an old channel.

Intrusive rocks underlie only a small part of the Angels Camp quadrangle, whereas they underlie about a fourth of the Sonora quadrangle. They are represented chiefly by stocks of gabbro and related rocks, chiefly diorite and serpentine. The serpentine rock generally is massive, but along major faults has been intensely sheared. Locally the serpentine contains viens of chrysotile, and some asbestos has been mined; elsewhere in the serpentine are small chromite prospects. The gabbro generally is medium- to coarse-grained and consists essentially of saussuritized plagioclase and amphibole. It is massive except near faults. Other intrusive rocks include mafic dikes of several types and quartz-bearing plutonic rocks.

The major structure of the mapped area is characterized by steep dips of beds and foliation; overturned, nearly isoclinal folds; and reverse faults. Most of the major folds plunge gently, whereas their axial planes dip steeply. In addition to these folds, formed by horizontal compression, some major folds apparently were formed by the intrusion of some of the larger stocks. Minor folds generally plunge steeply; most of them are probably drag folds associated with some of the faults and regional shear zones.

The Mother Lode fault system is a zone of anastomosing reverse faults and shears extending across the mapped area from northwest to southeast. The fault zone in this area ranges in width from about 1,000 feet to about 3 miles. In general the faults dip more gently than beds or cleavage, so that in places younger rocks have been thrust over older rocks. Some of the faults have been mineralized along part of their extent, and it is in such places that the larger or more productive vein mines are situated. Locally, within the Mother Lode fault system, rocks of the Amador group and fault-bounded lenses of serpentine, have been brought by faulting into close association with lenses of marble that are assumed to belong to the Calaveras formation. At least four periods of faulting have occurred in the mapped area, for longitudinal faults have been offset along transverse faults and these in turn have been offset along longitudinal faults; late normal movement has taken place along some of the older reverse faults.

Most of the pre-Tertiary rocks in the mapped area are foliated; nonfoliated rocks are the more massive intrusive rocks and the coarse volcanic breccia of the Logtown Ridge formation. Except on the noses of plunging folds, schistosity and bedding are approximately parallel. In parts of the mapped area a late shear cleavage has been superimposed on the regional schistosity. Shear cleavage is approximately parallel to the axial planes of minor folds, whereas schistosity is approximately parallel to the axial planes of major folds.

The linear elements in the mapped area include (1) fold axes, (2) long axes of stretched fragments, both in clastic and in pyroclastic rocks, (3) intersections of planes, chiefly bedding, schistosity, and shear cleavage, (4) crenulations due to minute displacements along planes of shear cleavage, and (5) slickensides and mullions on faults and quartz veins.

Nearly all the pre-Tertiary rocks in the mapped area are of dynamothermal types that belong to the chlorite zone of metamorphism. Only the rocks of Tertiary age have not been metamorphosed. The pre-Tertiary rocks of the chlorite zone have been subdivided, on a structural and mineralogic basis, into two subzones. The rocks lying to the west of one of the major Mother Lode faults, which forms the metamorphic boundary or isograd between the subzones, are only slightly altered and have been assigned to the chlorite 1 subzone. Their original textures and structures, and some of their original minerals, are largely retained. To the east of the metamorphic boundary the rocks have been considerably more altered and schistose structures have developed. These rocks have been assigned to the chlorite 2 subzone; they are largely reconstituted mineralogically, and only a few relict minerals remain.

About 180 mines and prospects have been identified by name on the accompanying maps. Gold is the most important mineral commodity in the area, both in quantity of ore produced and in dollar value. Gold has been recovered from quartz veins, mineralized schist, and river gravels of Tertiary and Quaternary age.

In addition to gold, the following commodities are reported to have been prospected or produced in the mapped area: asbestos, building stone, chromite, copper, limestone and marble, magnesite, manganese, road metal and riprap, roofing granules, and talc and soapstone. Silver and copper have been recovered as byproducts from the gold ore.

In many of the mines that have been large gold producers, fault zones near contacts between rocks of different types have been favorable locales for ore deposition. Ankeritization has been the most widespread hydrothermal alteration, and in places ankerite is a good indicator of the presence of gold ore. The fault system of the Mother Lode belt rather than the host rock probably was the chief controlling factor in ore deposition. Most of the mines with large production are alined along a narrow part of the Mother Lode fault system. Along this linear belt three areas have been especially productive: Angels Camp-Altaville, Carson Hill, and the area west and southwest of Jamestown.

Probably most of the gold near the surface has been recovered, but undoubtedly much gold remains. Some of the areas between the three most productive ones are favorable for more intensive exploration than has been done to date. Likewise, the fault zones 1½ miles west of Angels Camp and the one just west of Sonora merit further exploration. Unexplored areas also exist in the Tertiary river gravels, specifically in the Ceneral Hill Channel.

INTRODUCTION

Location and Topography. The area described comprises two 7½-minute quadrangles: the southeast quarter of the San Andreas 15-minute quadrangle (Angels Camp quadrangle) and the Sonora quadrangle. Figure 1 shows the location of the area. The Angels Camp quadrangle is bounded by latitudes 37°07′30″ and 38° N. and by longitudes 120°30′ and 120°37′30″ W.; the Sonora quadrangle by latitudes 38° and 37°52′30″ N. and by longitudes 120°22′30″ and 120°30′ W. Most of the Angels Camp quadrangle is in Calaveras County, whereas the Sonora quadrangle is almost entirely in Tuolumne County, California. Angels Camp, Sonora, and Jamestown are the principal towns in the mapped area.

The region is one of moderate relief, as the lowest altitude is about 735 feet at Melones Reservoir on the Stanislaus River and along Woods Creek, and the highest is 2,895 feet at the summit of Bear Mountain; the average altitude is about 1,500 feet. Bear Mountain, in the Angels Camp quadrangle, is a monadnock whose relief must be inherited from at least early Tertiary time, for apparently it deflected one of the principal early Tertiary streams of the region. Another conspicuous topographic feature is Table Mountain, a flat-topped, steepsided elongate and sinuous hill that extends across the Sonora quadrangle from northeast to southwest with gradually decreasing altitude. It is held up by the remnants of a lava flow that in late Tertiary or early Quaternary time streamed down and filled one of the major river channels then draining the region.

The country supports a growth of grass, oaks, and pines; chaparral grows on many of the hills. The climate is hot and dry in summer, cool and rainy in winter; snow is uncommon.

Purpose and Scope of Field Work. The area was mapped by the U. S. Geological Survey under a cooperative program with the California State Division of Mines. The purpose of the work was to prepare detailed geologic maps of parts of the Mother Lode region. Parts of the area have been mapped twice before by the Geological Survey, first by Turner and Ransome (Turner, 1894; Turner and Ransome, 1897) and later by Ransome (1900). The present survey attempts to solve some of the stratigraphic and structural problems of the area.

During the present survey the geology was mapped on aerial photographs, issued by the U. S. Forest Service, on a scale of about 1:20,000; for compilation, topographic maps on a scale of 1:24,000 (2,000 feet to the inch) were used. These scales are considerably larger than those heretofore used by the Geological Survey in regional geologic mapping in the Mother Lode region, and the resulting more detailed geologic maps afford a basis for new interpretations of the stratigraphy and structure. Rock units as narrow as 50 feet have been mapped, as have the major faults, quartz veins, and alteration zones. Because of inaccessibility of the mines, field work has been confined almost entirely to surface mapping.

Field Work and Acknowledgments. Field work was begun by John H. Eric and George R. Heyl in May 1946; Arvid A. Stromquist joined the party in September of the same year. In June 1947 C. Melvin Swinney was assigned to the project, and in September of the same year John H. Wiese joined the party. Swinney worked with the group on a part time basis. Heyl and Wiese were associated with the project for 14 and 10 months respectively. Mapping of the Angels Camp quadrangle was finished in November 1947 and of the Sonora quadrangle in August 1948.

The authors of this report are indebted to F. C. Calkins of the Geological Survey, who examined about 150 thin sections of rocks from the area. Many of the petrographic descriptions in this report are based on his notes.

Shirley Huddleston of the Geological Survey assisted in the compilation of the data on mines and prospects in the area; officials of Calaveras County in San Andreas, of Tuolumne County in Sonora, and of the California State Division of Mines in San Francisco and Sacramento also were helpful in this work. Several residents of the mapped area aided the authors in finding and identifying by name some of the mines that have long been abandoned. Walter Lyman Brown, of the Carson Hill Gold Mining Corp., allowed us to map the Melones adit.

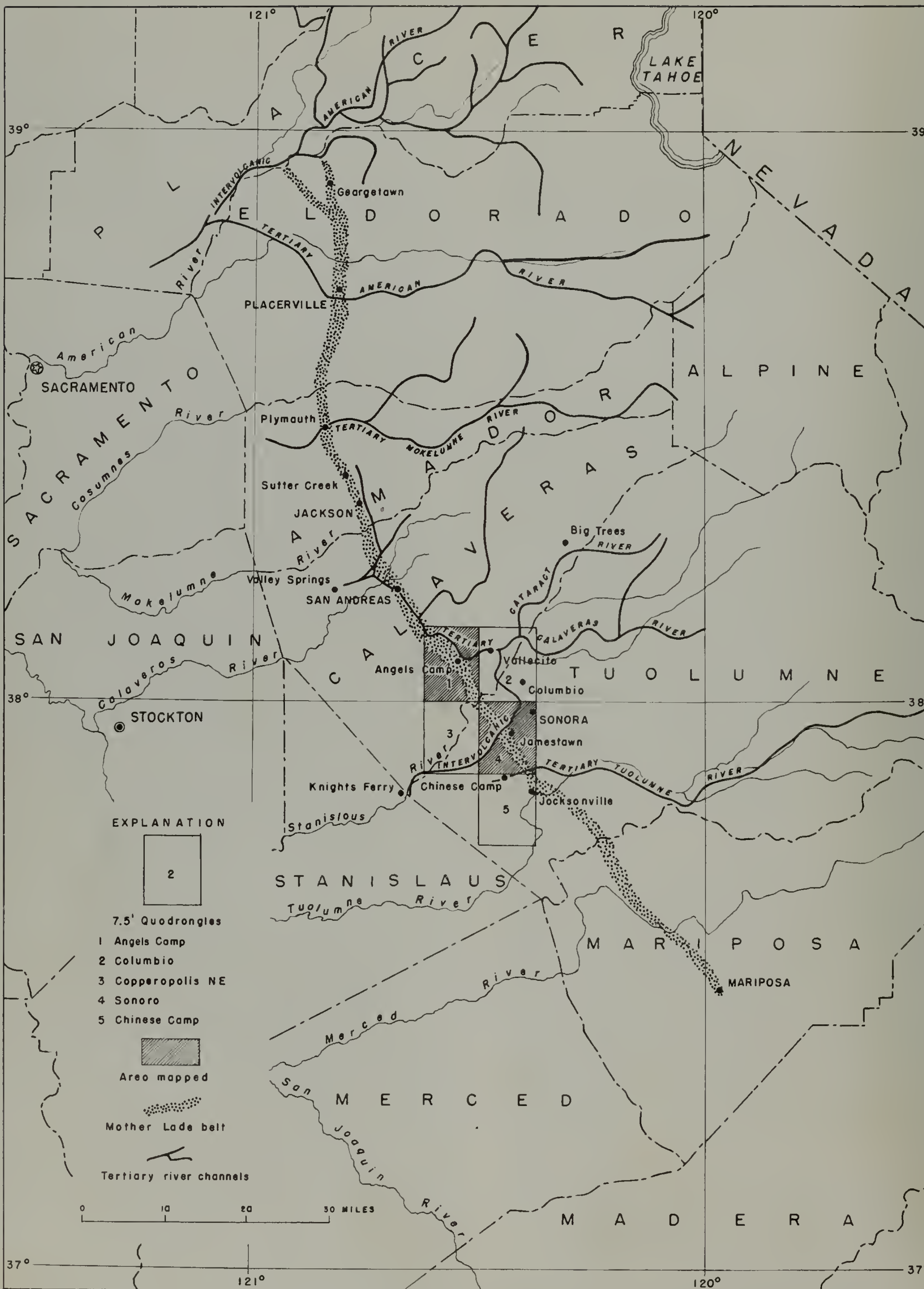

FIGURE 1. Index map showing the location of the Mother Lode belt, Tertiary river channels, and distribution of quadrangles referred to in the report.

Professor N. L. Taliaferro spent several days with the survey party in the field and his knowledge of the geology of the Sierra Nevada proved highly beneficial.

GENERAL GEOLOGY

The Mother Lode belt extends from the vicinity of Georgetown, El Dorado County, to the vicinity of Mariposa, Mariposa County, a distance of about 120 miles (Knopf, 1929, p. 1). The mapped area (fig. 1) is approximately at the geographic center of the belt. The Mother Lode fault system is a narrow fault zone about 1,000 feet wide at the south edge of the Sonora quadrangle, but to the northwest it branches and forms a zone 2 to 3 miles wide. Some of the individual faults and shear zones have been mineralized.

The Mother Lode fault system traverses a great variety of rocks. In the mapped area these rocks include marble, tectonic breccia, schist, and phyllitic material of probable Paleozoic age; phyllite, conglomerate, mica schist, and a green schist of uncertain but pre-Cretaceous age; and sedimentary, volcanic, and instrusive rocks of Jurassic age.

The marble has been assigned to the Calaveras formation of probable carboniferous age. Some of the sedimentary and volcanic rocks have been assigned to the Amador group, of Late or Middle Jurassic age, and to the Mariposa formation,[1] of Late Jurassic age. In this area the Amador group consists of a lower unit, the Cosumnes formation, made up largely of thin-bedded tuff and slate, sandstone, tuffaceous sandstone, and conglomerate; and an upper unit, the Logtown Ridge formation, which consists chiefly of coarse- to fine-grained metamorphosed pyroclastics. The Mariposa formation overlies the Amador group and consists chiefly of interbedded dark-gray slate, and metamorphosed siltstone, grit, graywacke, tuffaceous graywacke, and pebble conglomerate. The intrusive rocks of the mapped area range from ultramafic to felsic, but the commonest ones are serpentine and gabbro. Unaltered intrusive rocks, which are characteristic of the core of the Sierra Nevada, are absent in the mapped area.

The pre-Cretaceous rocks were dynamo-metamorphosed (Turner, 1948, p. 5) during the Nevadan orogeny in Late Jurassic time, and in many places no original constituents can be recognized. Despite this fact the grade of metamorphism generally is low, and most of the rocks are in the chlorite zone of metamorphism.

Like most of the Paleozoic and Mesozoic rocks of the western Sierra Nevada, the rocks in the mapped area have been folded and faulted. Open and isoclinal folds have been mapped. In general the dip of beds ranges from vertical to about 50° NE. Faults are present not only within the Mother Lode fault system but also in other parts of the area, and highly crushed, sheared rocks are commonplace. Schistosity is well developed over a wide area, and many of the rocks exhibit linear elements such as intersections of planes, long axes of stretched fragments, axes of minor folds, and striations on fault surfaces.

Quartz has been introduced along some of the faults. The quartz veins range in thickness from about 100 feet down to minute stringers measurable in fractions of an inch. The more conspicuous veins, known as "bull" quartz veins, are composed largely of milky quartz that contains very little gold; most of the gold ore shoots are in the mineralized wall rocks. Some of the quartz veins can be traced along their strikes for about a mile, but in general the veins occupy only short stretches along the faults in which they occur.

Unconformably overlying the pre-Cretaceous rocks described above are nearly flat-lying rocks of Tertiary age. These rocks include gravel; rhyolite tuff, andesite tuff, volcanic conglomerate, and siltstone; and a latite lava flow. The oldest of these rocks is a river gravel that has yielded sizable accumulations of placer gold.

STRATIGRAPHY

The rocks of the map-area are of two major categories, namely, a younger non-metamorphosed flat-lying series, and an older metamorphosed, steeply-dipping bedrock series. The explanations accompanying plates 1 and 2 describe and give the stratigraphic order of these rocks. The flat-lying series consist of river gravel, often gold-bearing, the Valley Springs formation, Mehrten formation, and a latite lava flow of Table Mountain. The bedrock series comprise rock units of Calaveras, Cosumnes, Logtown Ridge, and Mariposa formations, and various intrusive masses and dikes. In addition, green schists and related rocks, phyllites, and conglomerates of undetermined age have been mapped. However, in the geologic cross-sections these rock units have been tentatively correlated with the other formations present. The correlation has been based on lithologic similarities and geologic relations as far as possible.

Calaveras Formation of Paleozoic Age

Turner (1893) named the Calaveras formation from a belt of fossiliferous marble outcrops of Paleozoic age that lie along the west flank of the Bear Mountains in Calaveras County. Within the mapped area the rocks that have been assigned to the Calaveras formation are represented chiefly by marble, schist, and a tectonic breccia. Three discontinuous belts of Calaveras formation have been mapped.

Western and Central Belts. The western belt lies about a mile southwest of Bear Mountain and is represented in the mapped area by a single lens of marble along a fault zone in the southwest part of the Angels Camp quadrangle; however, other small lenses occur along this fault zone outside the mapped area.

Marble lenses of the central belt are distributed along, or adjacent to, faults and shear zones of the Mother Lode system and crop out along a narrow strip where they usually are associated with tectonic breccia or crush conglomerate. The largest of the marble lenses in this belt is about a mile long and has a maximum width of 600 feet.

The marble in the lenses of the western and central belts is fine- to medium-grained, crystalline, and pale blue-gray in color. It is commonly banded with fine-grained dark carbonaceous layers a fraction of an inch thick, and weathers light gray to brownish gray. Cylindrical crinoid columnals have been found in some of the marble lenses, and some of these fossils suggest a possible Paleozoic age; therefore, the marble and the tectonic

[1] The accepted name for this formation is the Mariposa slate, but inasmuch as the lithology varies considerably within the mapped area, and in places slate actually is a minor constituent, the name Mariposa formation is proposed.

breccia with which it is usually associated have been mapped as part of the Calaveras formation.

The tectonic breccia associated with the marble lenses has fragments that range from a fraction of an inch in diameter up to several feet in length. Other components of the tectonic breccia, in addition to marble, are fragments of chert, sandstone, quartzite, and quartz. Most of the fragments are rounded by attrition, but many are angular, especially those of quartzite. All are embedded in a very fine-grained matrix of crushed rock debris. Fine-grained quartz-mica schist and phyllite or phyllonite are locally closely associated and interfingered with the tectonic breccia. These rocks may represent original strata of fine-grained argillites, or possibly they are merely zones of more complete shearing along faults. Locally, thin, discontinuous, sharply crumpled beds of quartzite may be observed. In such areas, small boudins of quartzite occur where the strata have been pulled apart by intense shearing.

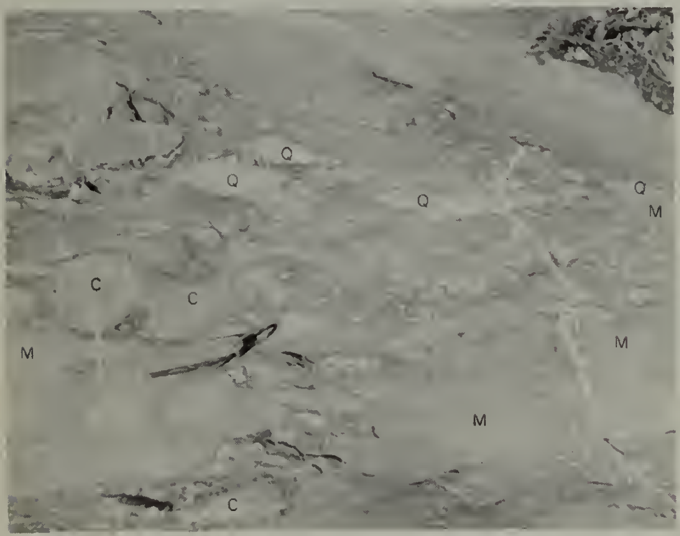

FIGURE 2. Tectonic breccia in the highly sheared Calaveras (?) formation. "Pebbles" consist chiefly of marble (M), chert (C), quartzite (Q). Mormon Creek, Sonora quadrangle.

Probably the original sequence of strata consisted of interbedded limestone, sandstone, shale, and chert, which, after intense shearing and metamorphism, is now represented by lenses of marble, tectonic breccia, schist, and phyllite or phyllonite. We believe, therefore, that in the central belt, as well as in the western belt, the Calaveras formation occupies a zone of major faulting. Figure 2 shows details of the tectonic breccia exposed along Mormon Creek in the Sonora quadrangle. In this area the Calaveras formation is about 2,000 feet wide. In figure 3 some of the highly sheared material commonly associated with the marble is shown cropping out between the light-colored marble exposures.

It has been suggested that in the western and central belts the marble lenses, many of which exhibit sharp minor folds in the banding, are the result of the plastic injection of the marble along fault zones; thus the marble lenses are not necessarily of the same age as the rocks immediately surrounding them (Heyl, 1947; Eric and Stromquist, 1948). Inasmuch as fossils have been found only in the marble lenses there is no positive way of correlating the age of the highly sheared surrounding rocks with that of the marble.

Near the lower part of Woods Creek in the southeast part of the Sonora quadrangle and northeast part of the adjacent Chinese Camp quadrangle, as well as to the north, just beyond the northwest corner of the Sonora quadrangle, a variety of rocks has been brought into juxtaposition along this control belt of major faulting. These rocks include marble, tectonic breccia, conglomerate, tuff, volcanic breccia, and gabbro and serpentine, of differing ages and stratigraphic positions.

Eastern Belt. The eastern belt of the Calaveras formation is represented in part, by the relatively large body of marble near the city of Sonora. Unlike the smaller discontinuous areas of Calaveras formation in the central and western belts, this larger body is not confined to a fault zone, but apparently is interbedded with quartzose rocks, chiefly micaceous quartzite, quartz-muscovite schist, and quartz-actinolite albite schist.

The marble of the eastern belt is massive, fine- to medium-grained, jointed, and shows only vague bedding or banding. It is gray and weathers to a very light gray. The noncalcareous rocks with which the marble appears to be interbedded are dark gray, finely crystalline, resistant rocks that consist of beds of slightly micaceous but nearly pure quartzite up to 3 feet thick interbedded with more argillaceous material, chiefly quartz-muscovite schist, and quartz-actinolite-albite schist. The sequence of marble and quartzose rocks has been assigned to the Calaveras formation, chiefly because the marble is lithologically similar to marble that has been mapped as Calaveras formation in other places. No diagnostic fossils have been found in the rocks, although structures of possible organic origin have been observed in the marble.

Black quartz-mica schist, locally graphitic and well bedded, that occurs in the northeast corner of the Angels Camp quadrangle has been assigned to the Calaveras formation. Farther north in the Calaveritas quadrangle quartz-mica schist is interbedded with limestone.

Age. The fossils discovered during the present survey do not permit an age assignment closer than Paleozoic for the Calaveras formation in this report.

Recognizable fossils were collected from several localities in small marble lenses in the Sonora quadrangle. One of these localities is about 4,500 feet southeast of Mormon Creek and 2,000 feet west of French Flat; according to Reeside,[2] "The only fossils that have survived recrystallization are crinoid stems. . . . These reach a large size and are of a type said to be most common in Mississippian rocks, but not confined to them." Concerning crinoid columnals found in marble in the same belt but only 1,500 feet southeast of Mormon Creek, Reeside [3] states that "Dr. Edwin Kirk, a crinoid specialist, expresses the opinion that the crinoid remains are of later Paleozoic age rather than Mesozoic, but no closer assignment can be made."

Crinoid stems found in other marble lenses in the mapped area and in a marble lens in the canyon of the

[2] Reeside, J. B., Jr., personal communication, June 27, 1947.
[3] Reeside, J. B., Jr., personal communication, November 22, 1946.

lower part of Coyote Creek, Columbia quadrangle, do not permit an age determination.

Relation of Age to the Catchall Calaveras Formation. The wide age span for the so-called catchall Calaveras formation is a direct result of the fact that no description exists for a type section of the Calaveras formation. Consequently, many different types of rocks have been mapped as Calaveras formation by various geologists in different areas. However, in this report the term Calaveras formation includes those rocks only that we believe to be Paleozoic in age because of paleontologic and geologic evidence.

The term Calaveras formation was introduced by Turner (1893), who first defined it as including all of the Paleozoic sedimentary rocks of the Sierra Nevada. Rocks of volcanic origin were excluded. Shortly thereafter he excluded certain formations in the northern Sierra Nevada that later were described by Diller (1908), namely, Silurian rocks and the Robinson formation of Pennsylvanian age, and thereby seemingly restricted the Calaveras to the Devonian and Mississippian.

Of the rocks previously assigned to the Calaveras formation, fossils have been found, so far as is known, only in the marbles. Lindgren (1900, p. 2) states that certain fossils found in the Calaveras formation near Colfax, Placer County, "can be unhesitatingly referred to the lower Carboniferous." The Committeee on Geologic Names of the Geological Survey considers the Calaveras to be Mississippian in age. However, Turner (1893) reported *Fusulina* at several localities, notably Hites Cove in Mariposa County and west of the Bear Mountains in Calaveras County, and if these fossils do occur their presence might be cause to doubt that the age of the rocks in which they are found is Mississippian, because fusulinids occur almost exclusively in rocks of Pennsylvanian and Permian age (Dunbar and Henbest, 1942, p. 80; Cooper, 1947, p. 267). Most of the older geologic maps of the Mother Lode region indicate that the Calaveras formation is Carboniferous in age. Nevertheless Turner (1894), for example, suggested that parts of the Calaveras might be "Juratrias" in age, and other parts older than Carboniferous. Knopf (1929, p. 10) thought that part of the Calaveras might be Triassic. Taliaferro (1943) has shown that some of the rocks previously mapped as Calaveras formation (Lindgren and Turner, 1894) are Jurassic in age. Turner (1896, p. 629) suggested that the name Calaveras formation was a temporary one, and that "as fast as definite horizons are recognized within the Calaveras formation they will be separated and designated under other names, so that if finally the age of all the contained horizons is ascertained there will be no longer any use for the term."

Taliaferro (1943) has pointed out that the term Calaveras is a catchall and has no stratigraphic significance. Moreover, the term has been variously interpreted by different geologists. It has been used to mean all the Paleozoic rocks of the Sierra Nevada; all of the Paleozoic sedimentary rocks of the Sierra Nevada; all of the Paleozoic sedimentary rocks of the Sierra Nevada except those of Silurian and Upper Carboniferous age; and the pre-Mesozoic bedrock of the Sierra Nevada south of the Taylorsville region. Some geologists apparently have used the term Calaveras to include all the rocks whose age is unknown or uncertain, or some or all of the rocks that "look older" by reason of their greater metamorphism and deformation.

Rocks that simply are more metamorphosed or deformed than nearby known Jurassic rocks should not necessarily be included in the Calaveras formation, because grade of metamorphism and amount of deformation are functions of tectonic history and environment, and not necessarily of age. Therefore, in the mapped area, we have excluded from the Calaveras formation certain rocks previously assigned to the Calaveras formation, because no valid evidence of Paleozoic age has been found.

In this report we use the term Calaveras formation as it was originally defined by Turner, i.e., it includes all rocks that are shown to be Paleozoic in age on the basis of paleontologic or geologic evidence.

Mesozoic Rocks

So far as is known, all of the Mesozoic rocks in the mapped area are of Jurassic age; the oldest of these rocks, the Cosumnes formation, is probably Middle or Late Jurassic in age; the youngest, the Mariposa formation, is of Late Jurassic age. The following Jurassic formations have been mapped in the two quadrangles and correlated, chiefly on lithologic and stratigraphic evidence, with the same formations outside the boundaries of the mapped area.

Group and formation		Age
	Mariposa formation	Late Jurassic
Amador group	Logtown Ridge formation	Middle or
	Cosumnes formation	Late Jurassic

Elsewhere the Amador group consists of several formations, but only two were recognized within the mapped area. The Mariposa formation consists of several distinct lithologic units, which have been mapped but not given formal names. Taliaferro (1943, pp. 282-284) has described the Amador group. At the northern type locality on the Cosumnes River, Amador and El Dorado Counties, the Amador is divided into two formations, the Cosumnes below and the Logtown Ridge above. Both of these formations are present in the Angels Camp and Sonora quadrangles. A generalized section of the Amador group along the Cosumnes River just west of State Highway 49 is given in table 1. According to Taliaferro (1943, p. 283), the Amador group at this locality is 7,100 feet thick, of which 4,400 feet is Cosumnes formation and 2,700 feet Logtown Ridge formation. In the mapped area, some of the rocks assigned to the Cosumnes formation were mapped previously by the Geological Survey as Calaveras formation; most of the rocks assigned to the Logtown Ridge formation were mapped previously as porphyrite, diabase and porphyrite and metaandesite.

Table 1. Generalized section of the Amador group, Cosumnes River, Amador and El Dorado Counties, California. Measured by G. R. Heyl, M. W. Cox, and J. H. Eric.

Formation and lithology	Apparent thickness (feet)	
Logtown Ridge formation		2,900±50
Agglomerate and volcanic breccia	400	
Pillow lava	35	
Agglomerate and volcanic breccia	875	
Tuff	85	
Agglomerate and volcanic breccia	490	
Tuff	60	
Pillow lava	40-85	
Agglomerate and volcanic breccia	900	

Table 1. Generalized section of the Amador group, Cosumnes River, Amador and El Dorado Counties—Continued.

Formation and lithology	Apparent thickness (feet)	
Cosumnes formation		5,100
Bedded tuff and fine-grained volcanic breccia	1,000	
Bedded tuff, sandstone, siltstone, slate, and thin conglomerate	2,000	
Dark blue-gray to black slate with considerable sandstone	600	
Coarse- and fine-grained conglomerate with many argillaceous interbeds	1,500	
Amador group, total thickness		8,000±50

Cosumnes Formation

Lithology, Distribution, and Thickness. The Cosumnes formation was first described by Taliaferro (1943, p. 283). The rocks assigned to the Cosumnes formation, in the southwest part of the Angels Camp quadrangle, consist dominantly of dark-gray to black slate and associated tuffaceous siltstone and sandstone, and of greenish-gray thin-bedded tuff. Southwest of Bear Mountain the rocks are chiefly tuff in beds that range in thickness from a fraction of an inch to 3 inches. These rocks underlie the much coarser, poorly bedded pyroclastics of the Logtown Ridge formation. Thin-bedded gray to reddish-brown chert is an abundant constituent in parts of the Cosumnes formation of this area. It occurs as thin lens-shaped bodies in the volcanic rocks. A few of the chert bodies are as much as 20 feet wide and 50 feet long but commonly they are much smaller. Phyllitic slate occurs in a few places, generally in beds 10 to 20 feet thick near the contact with the overlying Logtown Ridge formation. Northwest and north of Bear Mountain dark-gray slate, about 750 feet thick, with interbedded sandy and tuffaceous layers, underlies the Logtown Ridge formation; below the slate is about 750 feet of thin-bedded tuff that is very similar to the tuff southwest of Bear Mountain. The total exposed thickness of the rocks assigned to the Cosumnes formation is about 1,500 feet in the mapped area, but inasmuch as the base of the formation is not exposed the total thickness is greater.

In the Sonora quadrangle, near Quartz Mountain, the Cosumnes formation consists of black slate, tuff, and minor chert and conglomerate beds. Total thickness of the formation in this area is about 1,200 feet.

Age. The Cosumnes formation is considered to be of Late or Middle Jurassic age. Jurassic fossils have been found in the Amador group at several localities and according to Taliaferro (1943, p. 284) indicate an age older than the Oxfordian. Taliaferro believes that the age of the Amador group extends "from the upper Middle to the lower Upper Jurassic," although earlier he (1942) expressed doubt that the Amador actually does extend into the Middle Jurassic.

FIGURE 3. Marble lenses, white rock, in faulted zone. Highly sheared phyllitic rocks, dark exposures, are associated with the marble. North bank of Stanislaus River.

During the present investigation an ammonite was found in thin-bedded tuff of the Cosumnes formation, about 2,000 feet west of the contact between the Cosumnes formation and the overlying Logtown Ridge formation, on the north bank of the Cosumnes River about 2 miles below Huse Bridge (State Highway 49), and about 1,850 feet east of the west boundary of the Fiddletown quadrangle, El Dorado County. Imlay[4] states that this fossil "is a perisphinctid ammonite, but generic determination is not possible. As the perisphinctids first appeared in early Middle Jurassic time, the beds containing this ammonite cannot be as old as the

[4] Imlay, R. W., personal communication, January 17, 1950.

Lower Jurassic. . . . Perisphinctids similar to this ammonite are more common in the early Upper Jurassic than in older beds.''

Logtown Ridge Formation

In the mapped area the Logtown Ridge formation, the upper unit of the Amador group, consists predominantly of metamorphic rocks derived from coarse-grained, generally mafic, pyroclastics; mafic tuff; mafic flows; a little felsic tuff; and a few thin beds of tuffaceous shale. All of these rocks have undergone low-grade metamorphism. The formation was described by Taliaferro (1943, p. 283). One of the most characteristic and consistent units within the Logtown Ridge formation is a coarse-grained volcanic breccia and agglomerate composed chiefly of augite basalt and andesite fragments.

Augite Basalt and Andesite Breccia and Agglomerate. Volcanic breccia and agglomerate made up largely of augite basalt and augite andesite, and identical with the Logtown Ridge formation at the type locality on the Cosumnes River, occurs in several areas in the western and central parts of the two mapped quadrangles. The largest of these areas is that occupied by Bear Mountain, in the southwest quarter of the Angels Camp quadrangle. The coarse-grained fragmental nature of the rock can be observed conveniently in road cuts along State Highway 4 about 1,800 feet east of the west edge of the quadrangle, as well as along the road to the top of Bear Mountain.

The breccia and agglomerate are dark green, greenish gray, or gray. The maximum diameter of the blocks is slightly more than a foot, but most of the larger fragments have diameters that range from 1 inch to 3 inches. The fragments may be closely spaced, or separated from one another by a considerable amount of tuffaceous matrix. They may be angular or rounded. Most of the fragments are porphyritic; the phenocrysts commonly are crystals of augite, most of which are 1 to 4 mm in diameter but some are an inch across. Phenocrysts of saussuritized plagioclase are common. The tuffaceous matrix generally is of the same mineralogical composition as the larger fragments.

Light-gray glassy-looking fragments that appear to have been derived largely from dacite are also rather common. The sparse phenocrysts are quartz, augite, and highly saussuritized albite. Some of these fragments may be keratophyric rocks, as described by Knopf (1929, p. 16).

Amygdaloidal fragments also are common in the coarser-grained pyroclastics of the Logtown Ridge formation. Generally they are among the best rounded of the fragments. Many of these fragments are distinctly scoriaceous and appear to have been bombs; others are more angular and nonscoriaceous and contain only scattered amygdules. The amygdules are albite, calcite, chlorite, epidote, a green mica, and quartz; usually several different kinds of amygdules are associated, even in a single thin section. Some of the amygdules consist of two minerals, for example interiors of calcite and rims of albite.

The agglomerate and volcanic breccia of the Logtown Ridge formation also occur in other parts of the mapped area besides Bear Mountain. Good exposures of these rocks may be seen on Peoria Mountain, in the west part of the Sonora quadrangle; in the Angels Camp quadrangle, just east of the main belt of Mariposa formation; and in a small body, faulted along the east side, at the west boundary of the Sonora quadrangle north of the north arm of Melones Reservoir.

Tuff. Fine-grained volcanic rocks of the Logtown Ridge formation are exposed south of Table Mountain, and from there they extend in a strip nearly to the south edge of the Sonora quadrangle. In the Angels Camp quadrangle bedded tuff occurs in the belt of Logtown Ridge formation just west of Texas Charley Gulch, and in the belt just east of the main band of Mariposa formation. Particularly good exposures of bedded tuff showing graded bedding (top to the east) can be seen in road cuts just southwest of the road junction in sec. 15, T. 2 N., R. 13 E., about 3 miles south of Angels Camp. In general the rocks of these areas are fine-grained dense dark gray-green tuffs with a few layers of coarser-grained tuff that contain fragments of volcanic rocks up to 3 or 4 cm in diameter. The tuff appears to have been originally andesitic or basaltic in composition, though much of the plagioclase has been completely altered, and all of it has been at least partly altered (as has practically all the plagioclase in the Mother Lode region).

Conglomerate and Slate. Small lenses of conglomerate have been mapped along the contact between the Logtown Ridge and Cosumnes formations at four places in the southwest part of the Angels Camp quadrangle. The pebbles in this conglomerate are rounded to subangular, generally a quarter of an inch to an inch in diameter, and consist of vein quartz, intrusive rocks, dark fine-grained tuff, slate, phyllite, and mica schist. The conglomerate has been assigned arbitrarily to the Logtown Ridge rather than to the Cosumnes formation on the theory that it is basal and occupies local channels in the Cosumnes.

A small belt of dark-gray slate has been mapped in the southeast part of the Angels Camp quadrangle. This belt of slate is surrounded by volcanic rocks of the Logtown Ridge formation, and is here interpreted as part of that formation, although other plausible hypotheses are that the slate represents the Mariposa formation exposed in the trough of a syncline or, somewhat less likely, the Cosumnes formation exposed in the crest of an anticline.

Thickness. The thickness of the Logtown Ridge formation differs from place to place, which is to be expected in dominantly coarse-grained volcanic rocks. The formation is about 2,700 feet thick[5] (Taliaferro, 1943, p. 283) at the type locality on the Cosumnes River, west of Huse Bridge, whereas on Bear Mountain, near the headwaters of Brower Creek in the Angels Camp quadrangle, the thickness is about 1,500 feet; near the top of the mountain the thickness is at least 2,600 feet. In the Sonora quadrangle much of the Logtown Ridge formation has been cut out by intrusive bodies and faults, and consequently its thickness cannot be determined.

Age. The Logtown Ridge formation is of Middle or Late Jurassic age. Fossils, found by E. T. McKnight of the Geological Survey, were collected from the Logtown Ridge formation in the SE$\frac{1}{4}$ sec. 20, T. 1 N., R. 14 E.,

[5] Taliaferro, N. L.

just northwest of the junction of State Highway 49 and the road to Montezuma, in the Sonora quadrangle. The fossils occur in tuffs about 65 feet below the top of the formation.

Referring to these fossils, Imlay[6] says "The collection contains *Lima* cf. *L. dilleri* Hyatt, *Camptonectes* sp., and a *Tellina*-like pelecypod. These fossils cannot be definitely identified with species in our collections, but the *Lima* and *Camptonectes* closely resemble species in the Mormon sandstone of Middle Jurassic age in the Taylorsville region." However, if the underlying Cosumnes formation is early Late Jurassic in age at the type locality, it is unlikely that the Logtown Ridge formation is Middle Jurassic in age 50 miles away. Concerning perisphinctid ammonite from the type locality of the Logtown Ridge formation, Imlay[7] reports that the fossil "shows features that are more common among Kimmeridgian than among upper Oxfordian ammonites."

Mariposa Formation

The youngest pre-Cretaceous sedimentary formation in the mapped area is the Mariposa formation. The accepted name of this unit is the Mariposa slate (Wilmarth, 1938, p. 130), but inasmuch as the lithology varies considerably within the mapped area and in places slate actually is a minor constituent, the name Mariposa formation is proposed. Moreover, the proposed name is one that has been used generally by geologists, including Survey geologists. "Mariposa beds" was the name first applied by Becker (1885, p. 18) to the formation; no type locality has been described.

Distribution and Lithology. The Mariposa formation is exposed, in the mapped area, in a partly fault-bounded northwest-trending belt that lies just west of the Mother Lode fault system. Near the south edge of the Sonora quadrangle this belt is about 3,000 feet wide; near the south boundary of the Angels Camp quadrangle the belt is about 12,000 feet wide; and near the west edge of the Angels Camp quadrangle the belt is about 7,000 feet wide. A short distance south of the Angels Camp quadrangle this main belt splits, and a much narrower belt of Mariposa formation, 250 to 1,500 feet wide, is exposed just west of Bear Mountain; the narrow belt is a syncline, and it is interesting to note that Turner (1894a, p. 457), in a cross section, long ago showed the synclinal structure of the belt.

In the Sonora quadrangle about two-thirds of the rocks assigned to the Mariposa formation are dark-gray to black slates, and the rest are metamorphosed fine- to coarse-grained sandstone and grit, graywacke, pebble conglomerate, tuffaceous sandstone, and sandy to silty tuff. Slate is exposed in the Sonora quadrangle along Highway 49 where it crosses Slate Creek; and about half a mile to the east thin grit and conglomerate beds occur in the slates that crop out just northwest of the highway. In this same area thin dark-gray, fine-grained tuffaceous sandstone overlies the slate.

The Mariposa formation is thought to have a depositional contact with the Logtown Ridge formation along the east flank of Peoria Mountain and along parts of the flanks of Bear Mountain. In these areas the Mariposa consists chiefly of dark lead-gray slate with minor layers of grit and pebble conglomerate. Toward the east, near Peoria Mountain, tuffaceous and graywacke interbeds become common, although slate predominates. The eastern part of the Mariposa formation is cut off by faults of the Mother Lode fault system. In the mapped area the proportion of volcanic material increases toward the northwest, and in the western part of the Angels Camp quadrangle about 70 percent of the rocks assigned to the Mariposa formation is volcanic or partly volcanic in origin and consists chiefly of schistose sandy tuff and tuffaceous graywacke.

The possibility has been suggested that practically all the rocks of the Mariposa formation are essentially volcanic in origin. Such a hypothesis demands that the slates actually are merely a fine-grained facies (dust-tuff) of the volcanic rocks, and that they are not derived from detrital clay. Because of the fineness of grain, and the metamorphism that these rocks have undergone, evidence in the mapped area is inconclusive. However, the fact that in places the slate is composed largely of minute fragments of quartz suggests that some of the slate, at least, may be derived neither from detrital clay nor from dust-tuff, but rather from fine-grained silt.

A rather smooth cleavage is developed in most of the rocks of the Mariposa formation. In the fine-grained slates it is nearly perfect, and even in the sandy layers cleavage is good. In the grit, conglomerate, and graywacke layers cleavage generally is incipient or lacking, but even these rocks have been sheared in places and have developed a cleavage. Some of the tuffaceous layers have an irregular, primary schistosity, which is described below. Considerable local crumpling and sharp minor folds in beds are common in parts of the Mariposa formation, particularly in the slate units in the Sonora quadrangle. The axes of these minor folds generally plunge steeply, and they appear to be the result either of local drag along faults or of shearing with a strong horizontal component. In places quartz veins and pockets are associated with these minor fold axes.

Subdivisions. In the vicinity of Colfax, Placer County, the Mariposa formation has been subdivided by Smith (1910, charts opp. pp. 217, 222; 1916, pp. 30-31) into a lower formation, the "Mariposa slates," made up of dark slate containing *Aucella erringtoni* Gabb and *Cardioceras alternans*, (von Buch) [equals *Amoeboceras Dubium* (Hyatt)] and an upper unit, the "Colfax formation," composed principally of tuffaceous material and containing *Perisphinctes colfaxi* Gabb. Goranson (1924, p. 162) similarly divided the Mariposa formation. South of the Merced River, Taliaferro (1933, p. 149) has used the name "Mariposa group" to include two formations: a lower formation, the "Indian Gulch agglomerates, tuffs, sandstones, and conglomerates," and an upper formation, the "Mariposa slates."

Although evidence for such a twofold stratigraphic division of the Mariposa formation has not been found in the Sonora quadrangle, a division is possible in the Angels Camp quadrangle. In the southwest part of that area, particularly on parts of the southern and eastern flanks of Bear Mountain, the Mariposa formation lies with depositional contact upon metavolcanic rocks of the

[6] Imlay, R. W., personal communication, May 20, 1947.
[7] Imlay, R. W., personal communication, March 9, 1950.

Logtown Ridge formation and here the basal part of the Mariposa consists almost entirely of dark lead-gray slate with subordinate sandy and pebbly layers. Apparently overlying the slate to the east, although separated by a fault, are interbedded slate and tuffaceous rocks that may correspond to the Colfax formation of Smith.

Tuffaceous Sandstone. The sandstone of the Mariposa formation is chiefly graywacke as the term is defined by Pettijohn (1949, p. 227). It is composed of fragments of volcanic rocks, slate, phyllite, chert, augite, saussuritized plagioclase, and, in places, quartz, in a matrix of extremely fine-grained slaty and phyllitic material. The fragments are angular to subrounded and generally are less than 4 mm in diameter, and average 1 to 2 mm.

Interbedded with these essentially volcanic rocks are dark slates which, in the Angels Camp quadrangle, occupy an area only a fraction as large as the total area underlain by the volcanic rocks. Along the main belt of the Mariposa formation, east of Bear Mountain (pl. 1), the geology has been generalized; that is, thin slaty bands occur within the units mapped as volcanics, and, conversely, a few thin bands of volcanics occur within the units mapped as slate.

A detailed section across the Mariposa formation, measured along parts of Bower Creek and Angels Creek in the south-central part of the Angels Camp quadrangle, is shown in table 2.

As shown in the measured section, there are a few massive tuffaceous sandstone units, within the schistose tuffaceous rocks of the Mariposa formation that possibly could be assigned to the Logtown Ridge formation; these massive units, however, do not closely resemble any rocks known to belong to the Logtown Ridge formation in the mapped area; in particular they do not resemble the nearby augite porphyry greenstone breccia of Bear Mountain.

The tuffaceous sandstones and tuffs, here assigned to the Mariposa formation, bear no megascopic resemblance to rocks known to belong to the Logtown Ridge formation in the mapped area. Under the microscope, fragments of augite and of augitic greenstone can be seen; such fragments, it is true, do resemble those in the Logtown Ridge formation, but their presence is to be expected in rocks that overlie and presumably were derived in part from the Logtown Ridge formation; in other words, these augitic fragments are thought to represent merely the debris of the underlying formation. If the tuffaceous sandstones and siltstones are assigned to the Logtown Ridge formation, it is necessary to postulate, for this section, the existence of a great many small isoclinal folds, in which tuffaceous rocks (Logtown Ridge formation) occupy anticlines and slaty rocks (Mariposa formation) occupy synclines. Bedding is well shown in the excellent exposures along Brower Creek, but no folds are visible. The few graded beddings observed in the section all show tops to the east.

Thickness. The major structure of the main belt of the Mariposa formation, east of Bear Mountain, in the Angels Camp quadrangle, is not sufficiently known to warrant a measurement of thicknesses of the Mariposa formation.

In the southern part of the Sonora quadrangle and adjacent parts of the adjoining Chinese Camp quadrangle, graded bedding is unusually well developed in the Mariposa formation, and shows that the top of the section is toward the east. The Mariposa formation here is about 3,000 feet thick. To the west the Mariposa formation unconformably overlies the Logtown Ridge formation; to the east it is cut off by the Mother Lode fault zone, so that the top of the formation is not seen. According to Taliaferro (1933, p. 149) the Mariposa consists of more than 3,000 feet of acid and intermediate volcanics, sandstones, and cherts, and 2,000 to 2,500 feet of slates, making the total exposed thickness in this general region about 5,000 to 5,500 feet.

Age. The Mariposa formation is of Late Jurassic age. Three fossil localities were discovered in the Mariposa formation. Two of these are in the Sonora quadrangle, and one is to the south in the adjoining Chinese Camp quadrangle. Also, the well-known Texas Ranch locality is only a few hundred feet south of the south boundary of the Angels Camp quadrangle.

The fossils found in Long Gulch, about a mile south of Melones Reservoir, are poorly preserved and are not diagnostic, for they have been so crushed and distorted that species are not recognizable. However, *Belemnites* sp., *Aucella* sp., and fragments of ammonites can be identified, along with carbonized plant remains.

Concerning fossils found on the crest of a ridge about 1¼ miles northwest of Jacksonville, Chinese Camp quadrangle, Imlay [8] says "The fossils in the fine-grained conglomerate . . . consist mainly of an *Aucella* with fine radial striations that has commonly been called *Aucella erringtoni* Gabb and is characteristic of the Mariposa formation. . . ."

Fossils also were found in the canyon of Woods Creek about 1,500 feet north of the south border of the Sonora quadrangle. Imlay [9] states that the fossils are *Aucella erringtoni* Gabb and *Lamellaptychus* sp. He adds, "*Lamellaptychus* occurs in the Middle and Upper Jurassic and the Neocomian and represents the apertural covering of such ammonites as *Haploceras, Lissoceras, Oppelia,* and similar comparatively smooth forms. *Aucella erringtoni* is rather common in collections from the Mariposa slate."

The Late Jurassic age of the Mariposa formation has been known for many years, but paleontologists have been unable to agree on the proper stage to which the Mariposa should be assigned. Some say upper Oxfordian, and others say Kimmeridgian (Reeside, 1919, p. 10). Concerning the occurrence of *Aucella erringtoni* in the Mariposa formation, Imlay [10] says "Finely striate Aucellas, such as this species, occur commonly in the Pacific northwest and in the Arctic regions in beds of Kimmeridgian age and are rare in the upper Oxfordian. The age of at least the lower part of the Mariposa formation has been fixed by the occurrence of *Amoeboceras* (*Amoebites*) *dubium* Hyatt, as the subgenus *Amoebites* has been found consistently elsewhere only in beds of lower Kimmeridgian age." If the lower part of the Mariposa is Kimmeridgian, none of the formation can be Oxfordian. Smith (1916, p. 30) thought that the Mariposa formation was Kimmeridgian and Portlandian in age.

[8] Imlay, R. W., personal communication, October 14, 1946.
[9] Imlay, R. W., personal communication, March 5, 1947.
[10] Imlay, R. W., personal communication, March 5, 1947.

Table 2.—Section across Mariposa formation, measured along Brower Creek, and Angels Creek, Calaveras County, California *

	Thickness (in feet)	(feet)
SW.		
Logtown Ridge formation		
Fault		
Mariposa formation		
Not exposed	125	125
Dark-gray slate	40	165
Dark-gray tuffaceous siltstone, beds about 2 in. thick	45	210
Alternating coarser gray, finer dark-gray tuffaceous siltstone	90	300
Not exposed	55	355
Thin-bedded fissile tuffaceous siltstone	30	385
Dark-gray slate and fine gray tuffaceous siltstone, quartz stringers	25	410
Dark-gray slate and fine gray tuffaceous siltstone	30	440
Dark-gray slate	50	490
Dark-gray tuffaceous siltstone	30	520
Dark-gray slate	5	525
Dark-gray tuffaceous siltstone to 2 ft. thick, interbedded dark-gray slate to 3 in. thick	35	560
Dark-gray slate, interbedded tuffaceous siltstone	10	570
Dark-gray tuffaceous siltstone	20	590
Dark-gray slate, quartz stringers	5	595
Dark-gray tuffaceous siltstone, beds about 1 ft. thick	85	680
Gray tuffaceous siltstone, beds 2 to 3 ft. thick	10	690
Not exposed	60	750
Dark-gray slate, a little tuffaceous siltstone	20	770
Gray tuffaceous sandstone, fragments to 2 mm.	15	785
Not exposed	15	800
Tuffaceous siltstone, a little slate	30	830
Tuffaceous grit, fragments to 5 mm.	50	880
Tuffaceous siltstone	50	930
Tuffaceous siltstone, quartz stringers	5	935
Gray tuffaceous sandstone, with fissile silty layers up to 5 ft. thick	195	1130
Tuffaceous grit, fragments up to 5 mm.	50	1180
Gray tuffaceous sandstone	70	1250
Tuffaceous siltstone and dark-gray slate (50-50)	25	1275
Tuffaceous sandstone	25	1300
Dark-gray slate with tuffaceous siltstone	20	1320
Tuffaceous sandstone	20	1340
Tuffaceous siltstone and dark-gray slate	80	1420
Not exposed	35	1455
Dark-gray slate and tuffaceous siltstone	30	1485
Tuffaceous sandstone, fragments up to 1 mm.	100	1585
Tuffaceous sandstone with lenses of black "shale" up to 14 in. long and 1 in. wide	5	1590
Tuffaceous sandstone with a few 1-in. beds of dark-gray slate	40	1630
Tuffaceous sandstone, fragments up to 2 mm.	10	1640
Tuffaceous sandstone, fragments up to 1 mm.	40	1680
Tuffaceous sandstone with scattered 2-in. layers of tuffaceous siltstone	20	1700
Tuffaceous siltstone and dark-gray slate	30	1730
Tuffaceous siltstone, a little tuffaceous sandstone	40	1770
Tuffaceous siltstone, quartz stringers	10	1780
Tuffaceous siltstone, beds 1 to 6 in. thick	15	1795
Dary-gray slate and tuffaceous siltstone	30	1825
Tuffaceous siltstone	235	2060
Dark-gray slate	10	2070
Tuffaceous siltstone	10	2080
Milky quartz vein	5	2085
Massive tuff (Logtown Ridge?)	40	2125
Tuffaceous siltstone, scattered beds of tuffaceous sandstone	175	2300
Dark-gray slate	20	2320
Slaty tuffaceous siltstone	150	2470
Tuffaceous siltstone	80	2550
Massive tuff (Logtown Ridge?)	50	2600
Tuffaceous sandstone, fragments up to 2 mm.	130	2730
Tuffaceous grit, milky quartz pebbles, a few 1-ft. beds of slate and tuffaceous siltstone	120	2850
Fine-grained tuffaceous sandstone	75	2925
Tuffaceous grit	30	2955
Slate and tuffaceous siltstone	30	2985
Tuffaceous grit	35	3020
Tuffaceous siltstone	45	3065
Dark-gray slate and tuffaceous siltstone	75	3140
Dark-gray slate and tuffaceous siltstone, quartz stringers	20	3160
Tuffaceous siltstone	120	3280
Dark-gray slate, minor amounts of slaty tuff	30	3310
Tuffaceous siltstone	60	3370
Dark-gray slate, minor amounts of tuffaceous siltstone	100	3470
Tuffaceous siltstone, minor amounts of dark-gray slate	230	3700
Tuffaceous siltstone (approx. junction of Brower and Angels Creeks)	20	3720
Tuffaceous sandstone	30	3750
Tuffaceous siltstone	10	3760
Fine-grained tuffaceous sandstone	10	3770
Tuffaceous siltstone, minor amounts of fine-grained tuffaceous sandstone	30	3800
Tuffaceous sandstone, some silty	20	3820
Tuffaceous siltstone, some sandy	20	3840
Fine-grained tuffaceous siltstoue and dark-gray slate	30	3870
Fissile tuffaceous siltstone, a few beds of slate	40	3910
Tuffaceous siltstone, a few thin sandy beds	180	4090
Tuffaceous slate-siltstone	35	4125
Tuffaceous sandstone	5	4130
Fissile tuffaceous siltstone	80	4210
Dark-gray slate with tuffaceous siltstone interbeds. Exposures poor, float abundant	350	4560
Tuffaceous siltstone, minor amounts of slate	25	4585
Dark-gray slate, minor amounts of tuffaceous siltstone	145	4730
Not exposed	185	4915
Dark-gray slate, minor amounts of tuffaceous siltstone	105	5020
Tuffaceous siltstone	5	5025
Tuffaceous sandstone	10	5035
Tuffaceous grit, quartz pebbles	10	5045
Tuffaceous sandstone	35	5080
Tuffaceous siltstone	160	5240
Dark-gray slate, minor amounts of tuffaceous siltstone	60	5300
Not exposed	145	5445
Dark-gray slate	55	5500
Not exposed	35	5535
Fissile tuffaceous slate, tuffaceous siltstone, and dark-gray slate	45	5580
Dark-gray slate	60	5640
Not exposed	60	5700
Not exposed, slate float	210	5910
Dark-gray slate	240	6150
Fault		
Logtown Ridge formation		
NE.		

* This section may not be a stratigraphic section, as several major folds may be present; "thickness" therefore is not necessarily true thickness. In this section "siltstone" means that the rock is coarser than slate but most of the individual grains are barely visible to the unaided eye; "sandstone" means that the grains are easily visible but generally are less than 2 mm. in diameter; "grit" means that the grains in general are 2 to 4 mm. in diameter. In the table, graywacke is included under the term "sandstone." The section was measured by J. H. Eric, A. A. Stromquist, G. W. Walker, and F. G. Wells, on May 1 and 2, 1948.

Pre-Cretaceous Rocks of Uncertain Age

An area underlain chiefly by phyllite, stretched conglomerate, and green schist of undetermined, pre-Cretaceous age lies in general northeast of one of the main faults of the Mother Lode system. These rocks have not been assigned to any formation, although they have been tentatively correlated in part with the Cosumnes and Logtown Ridge formations. We believe they represent a more schistose and slightly more metamorphosed facies of those formations. Evidence pertaining to the tentative correlation of these rocks is discussed elsewhere in this report, under "Some problems of correlation."

Phyllite, Stretched Conglomerate, and Related Rocks. In the northeast part of the Angels Camp quadrangle the rocks have been more intensely metamorphosed than elsewhere in the quadrangle. Phyllite, quartz-mica schist, phyllonite, and conglomerate are the common sedimentary rock types in this part of the mapped area. Pebbles in the conglomerate have been stretched. Ratios of diameters of the pebbles are commonly in the order of 1:2:4 to 1:2:8.

Conglomerates and phyllites, derived from slates and thin-bedded tuffs, are well exposed near the southeast corner of the Angels Camp quadrangle. The conglomerate is an important mapping unit in this area because some of the layers are excellent markers and can be traced several miles. Although some of the conglomerate beds have been faulted into their present positions, probably they do not all represent faulted or folded parts of a single conglomerate bed.

The conglomerates and phyllites in the northwest part of the Sonora quadrangle, like those in adjacent parts of the Angels Camp quadrangle, are only slightly metamorphosed and consist of pebble conglomerate with interbeds of sandstone, slate, siltstone, and bedded tuff. The conglomerate contains pebbles of a great variety of rocks, including volcanic rocks, slate, schist, chert, mafic intrusives, quartz, quartzite, and marble. The marble in the pebbles bears a close resemblance to the marble that is assumed to belong to the Calaveras formation, but no fossils have been found in the pebbles. Many of the pebbles have been stretched, and ratios of the pebble diameters are in the order of 1:2:4.

Adjacent to the pebble conglomerate in the northwest part of the Sonora quadrangle are dark-gray siltstone and slate that contain minor amounts of sandstone, thin conglomerate beds, and bedded tuff and tuffaceous sandstone. These rocks have all been mapped as phyllite; in places they appear to grade into the pebble conglomerate. Their total exposed thickness in this area, including the conglomerate, is about 2,500 feet, but they are cut off by faults both to the northeast and to the southwest.

Phyllite, phyllonite, and fine-grained quartz-muscovite schist occur along the north edge of the Sonora quadrangle, near the city of Sonora, and in the vicinity of Rawhide Flat, Jamestown, and Stent. These rocks bear a close resemblance to rocks typical of the Cosumnes formation though they are of slightly higher metamorphic grade. Some beds, intercalated with phyllite and schist, contain pebbles that are much more distorted than those in the northwest part of the Sonora quadrangle; generally the pebble layers have been completely crushed and recrystallized to phyllonite. These rocks are dark gray-green, nearly black where fresh, but rusty gray-brown where weathered.

In the core of the major north-plunging anticline, southeast of Jamestown, the predominant rock type is dark-gray slate that contains layers of phyllite, sandy layers showing a phyllitic luster, and scattered conglomerate layers with stretched pebbles.

Green Schist and Related Rocks. A large area underlain by green schist lies in general to the east of one of the main faults of the Mother Lode system. Most of the rocks of the green schist have not been assigned to any formation on the geologic maps (pls. 1 and 2), but some have been tentatively correlated with the Logtown Ridge formation and are believed to represent a more schistose facies of that formation. Evidence pertaining to the correlation of these rocks is discussed elsewhere in this report under "Some problems of correlation." In the southwest part of the Angels Camp quadrangle several small areas of green schist have been mapped; because of more certain correlation, the green schist in these areas has been assigned to the Logtown Ridge formation.

In the Sonora quadrangle the green schist is well exposed along the road to Jacksonville in the southeast part of the quadrangle; along State Highway 49 between Jamestown and Sonora; and along the same highway north of Table Mountain, especially near Tuttletown. In the Angels Camp quadrangle the green schist covers wide areas and is exposed along Highway 49 for almost the entire distance through the quadrangle.

Most of the rocks of the green schist are dark green to brownish green and gray on weathered surfaces, but where fresh the schist generally is bright green to gray-green. Schistosity is well developed although locally it is absent in lens-shaped areas in which are preserved the original textures and structures of the pyroclastic rocks. Part of the green schist in the mapped area is clearly derived from coarse-grained agglomerate and volcanic breccia; the original texture can be well seen in the large area underlain by the green schist northeast of Altaville, especially on Brunner Hill. The coarse fragmental nature of the original rock can also be seen clearly in the area just north of Tuttletown.

Bedded tuffs are less abundant than coarse pyroclastic rocks in the green schist. However, bedded tuffs are well exposed along San Domingo Creek, east of Highway 49 in the north part of the Angels Camp quadrangle, and in parts of a narrow belt of the green schist extending from Carson Hill to Altaville. In hand specimen the tuff of this belt appears to be almost identical with non-schistose bedded tuff in the Logtown Ridge formation east of the main band of the Mariposa formation; the only difference is that the abundant dark-green augite crystals have been replaced by uralitic hornblende and actinolite crystals.

Flow rocks make up a small percentage of the green schist. Locally the flows show pillow structure; and in all cases observed, the tops of the pillows are to the east. These features can be observed along Sullivan Creek, especially where the road between Campo Seco and Algerine crosses the creek.

Three volcanic units within the mapped area are sufficiently distinctive to warrant their being mapped separately from the other volcanic rocks lumped into the green schist.

One map unit is fine- to medium-grained well-bedded amphibole crystal tuff with minor flows of interbedded hornblende andesite. The tuff is light gray to gray-green; the flows are dark green to nearly black. These rocks are best exposed along Sullivan Creek near the east edge of the Sonora quadrangle and on State Highway 49 just south of the city of Sonora. Near Sonora the rock is fairly massive, well jointed, and somewhat coarser-grained than elsewhere, and was originally mapped by Turner and Ransome (1897) as diorite.

The second map unit is a felsic, possibly rhyolitic, tuff, much of which has been metamorphosed to sericite schist. This rock is well-exposed in the Sonora quadrangle along Highway 49 between Sonora and Jamestown, and stands out in sharp contrast to the more typical green schist because it is lustrous white where fresh and rusty buff where weathered. To the south this unit becomes less schistose, contains less sericite, and grades into a fine-grained gray, slightly schistose tuff. Toward the north, near Altaville, rhyolitic tuff have been mapped but they are not extensive in area.

The third unit is hornblende andesite. This unit occupies two areas in the Angels Camp quadrangle, one just west of State Highway 49 between Carson Hill and Angels Camp, and one just south of the northwest corner of the quadrangle; it can be seen conveniently along the hillside half a mile due west of Frogtown. The rocks of this unit are chiefly metamorphosed massive flows and flow breccias; agglomerate may be present in a few places. The hornblende andesite is porphyritic and has small but conspicuous phenocrysts of euhedral green hornblende in a light greenish-gray fine-grained groundmass. In a few places quartz is an important constituent, and the rock is hornblende dacite, but these small areas have not been mapped separately from the main bodies of hornblende andesite.

The stratigraphic relations of the bedded amphibole crystal tuff, the sericite schist, and the hornblende andesite units have not been established.

Tertiary Rocks

Essentially flat-lying rocks of Tertiary age occupy parts of the mapped area. Their distribution, shown on the geologic maps (pls. 1 and 2), indicates that they occupied ancient valleys. Owing to their resistance to erosion, some of these rocks now stand as hills above the surrounding landscape. Three formations and one lava unit of Tertiary age have been mapped. These are: river gravel of Eocene (?) age; Valley Springs formation (interbedded rhyolite tuff and gravel); Mehrten formation (conglomerate, mudflows, agglomerate, breccia, and tuff that are essentiaally andesitic or basaltic throughout); and latite of Table Mountain.

River Gravel of Eocene (?) Age

The oldest rocks of Tertiary age within the mapped area consist of gravel and conglomerate with interbedded sand and sandstone. These rocks are exposed chiefly in parts of the Tertiary Calaveras River in the northern part of the Angels Camp quadrangle, where they are overlain by rhyolites and andesites; and also in the southern part of the Sonora quadrangle, where they are overlain by andesites. The gravels are well exposed in the hydraulic pit of the San Domingo mine (fig. 4), where their thickness is more than 100 feet. The larger fragments are pebbles, cobbles, and boulders of many kinds of bedrock and include pebbles of white vein quartz. The lowest part of the formation has yielded much gold.

On the early maps of the Mother Lode district, the "auriferous gravels," along with the other rocks of Tertiary age, were assigned to the Neocene, a term formerly used to designate Miocene and Pliocene. It is now known that not all the Tertiary rocks are of Miocene and Pliocene age. In fact, Lindgren and Knowlton (Knowlton, 1911, p. 57) recognized the deep gravel as probably Eocene in age. The exact age of the auriferous gravel in the mapped area has not been established, as no fossils have been reported from it. Similar deposits farther north, however, Chaney (1932, pp. 229-302) has called Eocene. Allen (1929) believes that these early gravels were deposited contemporaneously with the Ione formation of Eocene age a few miles to the west, and MacGinitie (1941) has referred to similar river gravels as "Ione gravels" and "Ione formation." We are uncertain of the age relations of the river gravel to the deposits of clay, sand, and lignite in the Ione formation farther west. In some areas, such as parts of the Sonora quadrangle and the northwest part of the Angels Camp quadrangle, where auriferous gravel locally does not underlie younger deposits, there may have been some reworking of the river gravel in Pleistocene time.

Valley Springs Formation

Unconformably overlying the auriferous river gravel of Eocene (?) age are rocks that have been mapped as the Valley Springs formation (Piper, et al., 1939, pp. 71-80). These rocks consist of interbedded rhyolite tuff and gravel. The gravel is identical with the underlying river gravel of Eocene (?) age from which it very likely was derived, so that, in this area, the presence or absence of rhyolite tuff was the sole means used to distinguish the two formations; the contact was arbitrarily placed at the base of the lowest observed layer of rhyolite tuff.

In the mapped area the Valley Springs formation is exposed only in the Tertiary Calaveras River, where it has a maximum thickness of about 200 feet, although rhyolitic lake beds have been reported (Bowen and Crippen, 1948, p. 50) in an old tunnel under Table Mountain near Jamestown. The Valley Springs formation is well exposed at only a few places, but at such places rhyolite tuff exceeds gravel in abundance. The tuff is white to light gray, compact, and fine-grained. Under the microscope it is seen to consist essentially of shards of glass with scattered crystals of sanidine, up to 3 mm in diameter, and of quartz, some of which is embayed. In a few places the tuff contains clear crystals of quartz up to 5 mm in diameter; one of these places is on the lower north slope of a hill half a mile east of Altaville, just east of the pipe line. In other places some of the tuff appears to be poor in quartz, and may be trachyte.

In addition to the interbedded rhyolite tuff and gravel, which comprise the greater part of the Valley Springs formation in this area, there are a few isolated hills composed of rhyolite tuff without gravel (pl. 1). These areas stand topographically higher than the rest of the formation, and therefore the nongravelly rhyolite tuff is

Figure 5. A latite lava flow overlies the Mehrten formation in this area and forms the cap of Table Mountain. A well indurated conglomerate member of the Mehrten formation crops out midway up the slope. Foreground is underlain by slate of the Mariposa formation.

Figure 4. San Domingo hydraulic pit, north part of Angels Camp quadrangle.

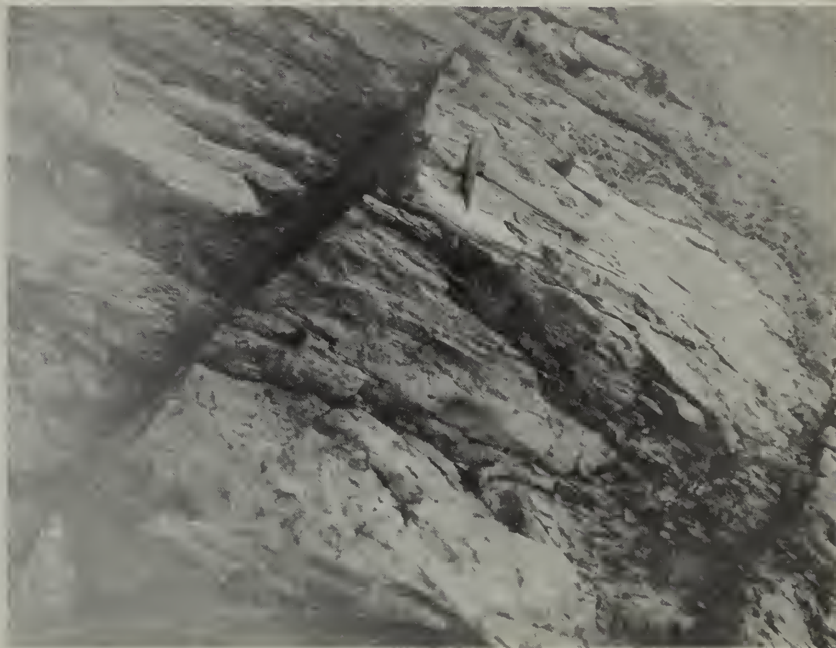

Figure 6. Stretched conglomerate containing marble pebbles. Lithologically similar marble pebbles occur in the Cosumnes formation at the type locality. (Point of pick points to marble pebbles).

assumed to occur in the upper part of the formation. One of these hills rests directly on bedrock, suggesting that the rhyolite tuff may once have been more extensive than the gravels and tuffs of the lower part of the formation, which were confined to the channel. The nongravelly rhyolite tuff may be remnants of one bed, although Julihn and Horton (1938, p. 45) write of "two distinct periods in which heavy blankets of rhyolite tuffs were laid down."

The age of the Valley Springs formation has not been established definitely, but it is probably Miocene. Piper, Gale, Thomas, and Robinson (1939, pp. 79-80) suggest that it may be correlated tentatively with the middle Miocene Salinas shale of the Coast Ranges. Miocene leaves were reported by Knowlton (1911, pp. 57-64) either from gravel just below the lowest beds of rhyolite tuff or from the lowest rhyolite tuff, in Placer and Nevada Counties, but studies by Chaney (1932, pp. 229-302) have suggested that these fossils are Eocene. Inasmuch as the fossils may have come from below the lowest rhyolite tuff, however, they may not be from the Valley Springs formation or its representative in Nevada County; another possibility is that there may be different ages of rhyolite tuff in the Sierra Nevada. For example, Jenkins (1935, p. 196) suggests that deposition of rhyolite ash began in Oligocene time.

Mehrten Formation

Unconformably overlying the Valley Springs formation is the Mehrten formation (Piper, et al., 1939, pp. 61-71). This formation is exposed in the northeast part of the Angels Camp quadrangle, where it attains a maximum thickness of about 300 feet and occupies essentially the same system of channels as the older Tertiary rocks. It is also exposed near Table Mountain in the Sonora quadrangle. In the mapped area the Mehrten formation is essentially andesitic or basaltic throughout, and consists of conglomerate, mudflows, agglomerate, breccia, and tuff, composed chiefly of hornblende andesite. The matrix of the pyroclastic rocks is similar in composition to the fragments. Fragments of andesite as much as 4 feet in diameter have been observed. Some of the conglomerate and agglomerate layers are so thoroughly indurated that they stand out as ledges and small cliffs as shown in figure 5. The rocks are bedded, although at many places the bedding is not readily apparent. In the vicinity of Table Mountain, laminated clay, siltstone, and ash are abundant. In some places, such as about $1\frac{1}{2}$ miles northwest of the Calaveras Central mine, fragments of rhyolite tuff and pebbles of bedrock from the underlying Valley Springs formation have been incorporated in the basal parts of the Mehrten. This makes it difficult to establish the contact between the two formations; however, the presence of fragments of andesite or basalt generally distinguishes the Mehrten from the underlying rocks. Although andesite in the form of fragments is by far the most common rock type in the Mehrten formation, fragments of other rocks are locally abundant. Boulders of granitic rocks, some as much as 5 feet in diameter, have been observed within the Mehrten formation.

Two principal types of andesite or basalt are present: one is dull red, the other white to light gray. Both types contain easily visible phenocrysts of plagioclase and amphibole, and in both types the plagioclase is shown, by measurement of refractive indices, to have a composition of approximately An_{45}, although maximum extinction angles suggest that some of the plagioclase may have a composition closer to An_{60}. The plagioclase in the red variety is faintly zoned, whereas much of that in the white kind is well zoned. The red rock contains highly pleochroic basaltic hornblende, with a small extinction angle, as well as augite, hypersthene, and magnetite. The white andesite contains common hornblende, a little magnetite, and apatite; pyroxene is less common.

Fossils were found in laminated clay and siltstone below andesitic volcanics in the Pulpit Rock adit, about half a mile northwest of Jamestown. According to Brown [11] the collection represents the so-called Table Mountain flora, and contains the following fossils:

Quercus convexa Lesquereux
Carya typhinoides (Lesquereux) Condit
Persea coalingensis (Dorf) Axelrod
Cercocarpus antiquus Lesquereux
Ilex opacoides Condit
Mahonia sp.
Ribes or *Crataegus* sp.

According to Condit (1944, p. 74) the Table Mountain flora, which is from deposits near Columbia, California, indicates "a transitional Mio-Pliocene age." However, some uncertainty seems to exist as to the formation, and even the nature of the rocks, from which the fossils were collected. We have assigned the laminated clay, siltstone, and ash of the Pulpit Rock adit and other places under Table Mountain to the andesitic Mehrten formation. Knowlton (1911, p. 57) says that the leaves collected at the Columbia locality are from the upper part of the andesite. Chaney (1932, p. 299) says that they were found in "tuffaceous shale." Louderback (1934, p. 12) says that they came from "andesitic sediments." Jenkins (1935, p. 193, fig. 31) in a cross section of Table Mountain, shows the fossil locality as " 'pipe clay' [rhyolitic ash] lake-bed silt," below the lowest andesite. Piper, Gale, Thomas, and Robinson (1939, p. 70) state that the fossils came from "andesitic sediments that are presumed to be equivalent to the lower part of the Mehrten formation." Condit (1944, pp. 59, 73) says that the fossils came from "andesitic sediments."

The laminated clays, siltstones, and ashes that are predominantly andesitic probably are correctly assigned to the Mehrten formation; if any are chiefly rhyolitic they may belong to the underlying Valley Springs formation. Study of four thin sections from the mapped area, one of thin-bedded white laminated siltstone and the others of pale-gray ash, shows that these rocks are predominantly andesitic in composition. Unlike the rhyolite tuff of the Valley Springs formation, this ash and siltstone contain only minor amounts of potash feldspar, quartz, and glass, but large amounts of basaltic hornblende and augite; and measurement of maximum extinction angles shows that the feldspar is about An_{50} in composition, and some may be even more calcic. Such a mineral composition suggests that the laminated clay, siltstone, and ash of the mapped area, though chiefly andesitic in composition, have been contaminated by fragments of older rhyolitic rocks and that they are properly assigned to the Mehrten formation, and not to the Valley Springs formation.

[11] Brown, R. W., personal communication, January 2, 1947.

Latite of Table Mountain

The most prominent topographic feature in the Sonora quadrangle, though not the highest eminence, is Table Mountain, a flat-topped, steep-sided, elongate and sinuous hill that extends across the quadrangle from northeast to southwest with a gentle southwesterly slope. The hill is formed by a resistant cap of latite, the remnant of a lava flow that in late Tertiary or early Quaternary time streamed down and filled one of the major river channels then draining the region. The maximum thickness of the latite cap is about 200 feet, and in the mapped area the latite-capped hill now forms the divide between the drainage basins of the Tuolumne and Stanislaus Rivers.

The latite has been described in detail in a paper by Ransome (1898), where the term ''latite'' was first used. A chemical analysis of the rock, made for Turner (1894, p. 491) and quoted by Ransome (1898, p. 58), from samples taken near Shaws Flat, just north of the Sonora quadrangle, is given below. Ransome says (1898, p. 10), ''the distinctive chemical feature of these rocks is a rather high percentage of total alkalies, with the total potash somewhat in excess of soda. Chemically they stand between typical andesites and typical trachytes, and belong to a general chemical group of the effusive rocks which it seems necessary to classify under a new name.'' Accordingly, Ransome (1898, p. 64) proposed the name latite, from the Italian province of Latium, where similar rocks are abundant, for the extrusive equivalent of monzonite.

Chemical analysis of latite of Table Mountain, near Shaws Flat. (Turner, H. W., U. S. Geol. Survey 14th Ann. Rept., p. 491. W. F. Hillebrand, analyst.)

SiO_2	56.19
TiO_2	.69
Al_2O_3	16.76
Fe_2O_3	3.05
FeO	4.18
MnO	.10
MgO	3.79
CaO	6.53
BaO	.19
Na_2O	2.53
K_2O	4.46
P_2O_5	.55
H_2O above 100° C.	.66
H_2O below 100° C.	.34
SrO	tr.
Li_2O	tr.
Total	100.02

In the Sonora quadrangle the rock is augite latite porphyry. The phenocrysts consist of labradorite, some as calcic as AN_{58} and up to 15 mm long; dark-green to pale greenish-brown to colorless augite; and brown olivine. The groundmass consists of labradorite, augite, olivine, magnetite, apatite, and glass. In places the rock contains andesine instead of labradorite. Potash feldspar has not been detected. Ransome (1898, p. 58) points out that some of the analyses of latites from the Sierra Nevada show ''as much as 5 percent of potash, which, if it were present in the form of orthoclase, would make up nearly 30 percent of the rock.'' Ransome believed that the potash occurs in the glass of the groundmass. However, the latite in the mapped area seems to contain an insufficient amount of glass to account for the reported potash. The rock was studied with the aid of a universal stage, and it was noted that the plotted position of the poles of twinning axes of plagioclase phenocrysts consistently lie to the left of the standard curves of Duparc and Reinhard (1924) and Nikitin (1936). Possibly this departure might be due to the presence of orthoclase in solid solution in the plagioclase. Departures from the standard curves have been discussed by Turner (1947), who noted that Barber (1936) ''dismissed variation in potash content'' as one of the causes. However, Turner (1947) believes that such departures might be caused by a chemical influence. The possibility that potassium, in solid solution in the plagioclase, has an effect on the position of the twin axes should not be overlooked. Moreover, the standard curves were based on study of plutonic rocks; therefore, they need not necessarily apply to volcanic rocks, such as the latite of Table Mountain, which crystallized under different physical conditions.

The latite of Table Mountain occupies a buried valley, known as the Cataract Channel, that was cut in the Mehrten formation. Therefore, the latite must be younger than the youngest part of the underlying Mehrten formation. The Mehrten formation is regarded as of Miocene and Pliocene age, so that the latite could be as old as Pliocene. Jenkins (1948, p. 27) believes that the latite is late Pliocene. The river channel down which the latite flowed is older than the present drainage pattern, for not only does the latite in some places cross the course of modern streams, but also, in the mapped area, it forms the divide between the modern drainage of the Tuolumne and Stanislaus Rivers. Accordingly, the latite could be as young as early Pleistocene but probably is older than late Pleistocene.

Some Problems of Correlation

One of the serious geologic problems encountered in the western part of the Sierra Nevada is the correlation of stratigraphic units. Consequently, certain phyllites, conglomerates, and large areas mapped as green schist have not been assigned to any formation on the maps. However, we have found indirect evidence suggesting that some of these rocks may tentatively be correlated with the Cosumnes and Logtown Ridge formations; in other words, that these rocks are slightly more metamorphosed equivalents of the known Jurassic units farther west. Thus, phyllite and related rocks such as phyllonite, stretched conglomerate, and thin-bedded tuff are tentatively correlated with the Cosumnes formation; the green schist and related rocks are tentatively correlated with the Logtown Ridge formation. This tentative correlation is based chiefly on lithologic similarity and partly on apparent stratigraphic relations. Therefore, we emphasize that the correlation here proposed is tentative and that no age assignment is made.

However, all marble bodies, and fault-bound bodies of rock containing lenses of marble, tectonic breccia, and some phyllite and schist have been assigned to the Calaveras formation.

Correlation of Marble and Interbedded Rocks

In the earlier geologic investigations of the Gold Belt the rocks of the chlorite 2 subzone generally were mapped as Calaveras formation and associated amphibolite schist, not only because of their greater metamorphism and deformation, but also because in places certain associated marble lenses contain Carboniferous fossils. As Ransome (1900, p. 2) says, "The fossils . . . indicate that the limestones are of Carboniferous age. Accordingly, that portion of the Calaveras formation in which the limestone lenses occur must also be Carboniferous."

Eric (1948) points out that where small marble lenses and associated tectonic breccia are bounded by faults, the rocks outside the fault-bound rocks may be of a different age from those within the faults.

In the mapped area, bodies of marble and associated tectonic breccia have been assigned to the Calaveras formation. This assignment is based on the arbitrary assumption that all the blue-gray marble in the area is Paleozoic in age. The schist east of the marble near Sonora has been assigned to the Calaveras formation because it seems to be interbedded with the marble. However, the two types of rocks might be isoclinally interfolded.

Tentative Correlation of Phyllite, Stretched Conglomerate, and Related Rocks

The sedimentary rocks of the chlorite 2 subzone consist chiefly of phyllite, phyllonite, stretched conglomerate, and chert. The phyllite appears to have been derived in part from shale and in part from thin-bedded tuff. As stated previously, we believe that there is evidence to suggest a tentative correlation of some of these rocks with the Cosumnes formation. This evidence is briefly reviewed.

(1) Conglomerate is one of the readily mappable lithologic units in the chlorite 2 subzone and is well exposed in parts of the Angels Camp quadrangle; in the Sonora quadrangle mappable units of conglomerate are restricted to the northwest part. Except for the fact that the pebbles are stretched, the conglomerate is similar to the conglomerate at the type locality of the Cosumnes formation on the Cosumnes River.

(2) Stretched pebbles of blue-gray marble (fig. 6) lithologically similar to the marble in mappable bodies, are scattered through the conglomerate. The marble in mappable units has been assigned to the Calaveras formation; and the presence of similar marble as stretched pebbles in the conglomerate suggests that the conglomerate is younger than the Calaveras. Certainly the conglomerate is younger than the marble from which the pebbles were derived. Similar marble pebbles occur in the Cosumnes formation at the type locality.

(3) Much of the rock mapped as phyllite has been derived from thin-bedded tuff, especially in the southeast part of the Angels Camp quadrangle and the northwest part of the Sonora quadrangle. Except for slightly greater metamorphism these rocks are similar to thin-bedded tuff at the type locality of the Cosumnes formation. Turner (1894), in fact, originally mapped these rocks as "Mariposa slates," because of a Jurassic ammonite reported by Whitney (1880, pp. 37, 41), although later Turner and Ransome (1897; Ransome, 1900) remapped them as Calaveras formation.

(4) In the northwest part of the Sonora quadrangle, about half a mile southwest of Jackass Hill, somewhat phyllitic thin-bedded tuff and conglomerate, closely resembling the rocks of the Cosumnes formation at the type locality, are associated with a highly augitic greenstone. The greenstone is identical in every respect with the Logtown Ridge formation at the type locality, as well as with the Logtown Ridge on Bear Mountain and Peoria Mountain in the mapped area. This association of thin-bedded tuff and conglomerate of unknown age with rocks similar to the Logtown Ridge formation suggests that the tuff and conglomerate belong to the Cosumnes formation.

Tentative Correlation of the Green Schist and Related Rocks

Large parts of the chlorite 2 subzone within the mapped area consist of green schist derived from breccia, agglomerate, tuff, and flows. Like the closely associated phyllitic rocks, the green schist is of unknown age, but evidence has been found which suggests that some of it may tentatively be correlated with the Logtown Ridge formation. This tentative correlation is supported by the following evidence:

(1) About $2\frac{1}{2}$ miles west of Angels Camp, Cherokee Creek crosses the Logtown Ridge formation and drops abruptly into a valley underlain by slate of the Mariposa formation. The Logtown Ridge at this place is a massive greenstone rich in augite and resembles in every way the Logtown Ridge at the type locality. Both contacts of the Logtown Ridge are major faults but the west contact is not exposed at this place. At the east contact and for at least 40 feet across the strike, the rocks of the Logtown Ridge formation have been intensely sheared and converted into actinolite schist. This suggests that typical massive augitic greenstone of the Logtown Ridge formation can grade across the strike, within a space of a few feet, into actinolite schist typical of the green schist.

(2) In places where exposures are good the green schist may be seen to contain "islands" or pods of rocks having typical Logtown Ridge lithology. One of the best places to see these pods is in a road cut at a sharp curve in Highway 49 about half a mile west of Tuttletown. The pods are composed of massive coarse-grained augitic pyroclastic rocks; yet for thousands of feet across the strike on both sides the rocks are typical green amphibolite schists. Another place where similar abrupt gradations may be seen between amphibolite schist and massive augitic pyroclastic rocks is in the Columbia quadrangle on the south side of Carson Hill about 100 feet east of Highway 49 at the hairpin turn at altitude 1,100 feet. Possibly the islands are patches of the original pyroclastic rock that have escaped the shearing and deformation experienced by the rest of the rocks of the green schist. Grain size may have been one of the controlling factors, as most of these bodies have coarse-grained texture.

(3) Relict crystals of augite in rocks of the green schist have optic angles of 35° to 40°, which is in the same range as optic angles of the augite crystals in the Logtown Ridge formation in the chlorite 1 subzone. It seems unlikely that augite from two separate magmas would have attained the same degree of equilibrium, whereas augite crystals from the same magma would vary only within narrow limits. That the augite was in equilibrium with the liquid phase is suggested by the almost complete lack of zoning in crystals from the massive Logtown Ridge formation as well as in relicts from the rocks of the green schist. The similarity of the augite crystals in the Logtown Ridge formation to the augite relicts in the green schist suggests, but does not prove, a possible close genetic relationship between the two rocks.

(4) A relatively small area southwest of Bear Mountain, in the Angels Camp quadrangle, is underlain by rocks of the chlorite 2 subzone. These rocks, despite their somewhat greater metamorphism, have been assigned to the Amador group because of their lithologic similarity to the Amador group and because of their stratigraphic relations. Thin-bedded tuff has been assigned to the Cosumnes formation, whereas the rocks of the green schist derived from coarse-grained pyroclastic rocks have been assigned to the Logtown Ridge formation. The two formations, in this area, are exposed in several belts that are inferred to be gently plunging anticlines and synclines.

INTRUSIVE ROCKS

The intrusive rocks of the area are younger than the sedimentary and volcanic rocks, which are of pre-Cretaceous age. With the exception of a few quartz-bearing intrusive rocks in the Angels Camp quadrangle they are mafic and ultramafic, and are represented chiefly by stocks of gabbro and serpentine as well as by many metamorphosed mafic dikes that intrude the older rocks. Intrusive rocks underlie only a small fraction of the Angels Camp quadrangle, whereas they underlie about a fourth of the Sonora quadrangle. The intrusives have not metamorphosed the adjoining rocks except in one area, in the southeast part of the Sonora quadrangle, where a narrow body, possibly a roof pendant, has been converted in part to spotted chiastolite schist.

Serpentine

Two irregular shaped stocks of peridotite, now converted to serpentine, have intruded rocks of the Amador group and Mariposa formation in the Sonora quadrangle. The larger of the two bodies is in the southwest part of the quadrangle and extends to the west, northwest, and south, beyond the limits of the quadrangle. The other body of serpentine is entirely within the quadrangle and extends northwestward from about a mile southwest of Stent to French Flat. In the Angels Camp quadrangle massive serpentine is found chiefly on Carson and Chaparral Hills, and is associated with gabbro. Massive serpentine also is found scattered, probably as inclusions, through the gabbro that extends northwestward along Highway 49 toward Angels Camp, and thus, in that area, seems to be restricted to the Mother Lode fault system. A highly foliated and slickensided variety of serpentine occurs southwest of Bear Mountain, where it is associated with altered granodiorite and diorite; some of it has been prospected for chromite. No peridotite has been seen in the mapped area, but there is some a few hundred feet to the south in the Chinese Camp quadrangle.

Areas underlain by serpentine commonly are marked by a characteristic growth of brush, a feature clearly discernible on aerial photographs. The serpentine rock generally is massive, dark green to almost black, and weathers to lighter green and buff. The weathering clearly discloses the minute magnetite veinlets that are distributed throughout the rock. Bastite pseudomorphs are common in the massive serpentine.

Locally the serpentine is intensely veined with cross-fiber chrysotile. Individual veinlets are about 1 mm thick and 2 to 3 mm apart, all roughly parallel. Locally the chrysotile veinlets attain a thickness of about an inch, and near Rawhide Flat some asbestos has been mined. In general, these small chrysotile veinlets lie in planes nearly at right angles to sheared joint surfaces or minor faults, but at an acute angle to grooves and striations on the slickensided shear surfaces.

The serpentine is intensely sheared along major faults. Irregular rounded pods of massive serpentine, ranging from an inch to 3 feet in diameter, are suspended in a matrix of crushed and granulated serpentine. The surfaces of the rounded serpentine pods are highly slickensided and polished, contrasting strongly with the dull massive unsheared rock. Such intensely sheared serpentine is well exposed where the road from Rawhide Flat to Melones Reservoir crosses one of the main faults of the Mother Lode system, about half a mile southwest of Rawhide Flat.

Several areas of similar intensely sheared serpentine are found in the serpentine body along the west edge of the Sonora quadrangle, just north of Table Mountain, but no faults have been mapped in these areas because of the poor exposures. There are many small chromite prospects in the areas of sheared serpentine in this body, and in a few places chromite has been mined.

Gabbro and Diorite

Two bodies of a somewhat less mafic rock that is predominantly gabbro are closely associated in the Sonora quadrangle with the two main areas of serpentine. A third main body of gabbro, not associated with serpentine, crops out in the southeast part of the quadrangle. A few small areas of slight compositional variation within the gabbro have not been delineated on the geologic map of the Sonora quadrangle. In the Angels Camp quadrangle small bodies of a light-colored facies of the gabbro have been mapped as diorite.

In the vicinity of French Flat (pl. 2) the outcrop pattern strongly suggests that the gabbro is intrusive into the serpentine and that it has enclosed many small "islands" of serpentine. Careful observation of the contact between the two rocks, however, seems to show conflicting evidence. In some places small fingers of gabbroic material extend into and enclose the serpentine, as though the gabbro were the later of the two rocks. Elsewhere the reverse is true, and serpentine encloses coarse-grained gabbroic rock. The contacts between the two rocks are gradational. Such relationships would seem to indicate almost contemporaneous intrusion of a mafic magma or differentiation in place. Almost identical relationships between serpentine and gabbro in an area in the foothills of the Sierra Nevada northeast of Visalia have been described by Durrell (1940, p. 74). There, according to Durrell, the two rocks represent either a single intrusive differentiated in place or two intrusives very closely related in time.

In the Angels Camp quadrangle gabbro, locally grading in composition to diorite, occurs in small scattered lenses confined chiefly to the Mother Lode fault system. In the vicinity of Carson and Chaparral Hills, it is associated with massive serpentine.

The gabbro generally is a medium- to coarse-grained rock and consists essentially of saussuritized plagioclase and dark minerals, chiefly hornblende. The rock is fairly light-colored, although in areas where hornblende is abundant the color may be dark green to nearly black. Locally, the gabbro is dark gray-green, fine-grained, and dense, especially along contacts with sedimentary and volcanic rocks.

The gabbro bodies generally are massive and poorly jointed, although some of those in the Angels Camp quadrangle are crudely foliated. Such secondary foliation has developed along faults and sheared contacts, as may be seen where Highway 49 crosses the small body of gabbro just west of the village of Carson Hill. In the southeast part of the Sonora quadrangle, poorly developed flow banding along the edges of the gabbro also gives the rock a crude foliation.

Hornblendite

Massive hornblendite has been mapped in four small areas in the Sonora quadrangle: two of these are associated with gabbro in the southeast part of the quadrangle; one is associated with gabbro and serpentine along the south boundary of the quadrangle near Highway 49; and one is associated with gabbro and serpentine along Highway 49, 2½ miles southwest of Jamestown. In the Angels Camp quadrangle hornblendite has not been separately mapped but occurs as very small bodies associated with gabbro and serpentine on Carson Hill, and with diorite just west of the head of Texas Charlie Gulch and just north of the Vallecito Western mine. The rock is dark green to nearly black. Crystals of hornblende, up to half an inch long, form the chief constituent, but actinolite also is present. Interstitial to the hornblende is saussuritized plagioclase, chlorite, epidote, a little clear albite, and minor amounts of prehnite.

Porphyritic Diabase

Massive feldspar porphyry occurs as dikes and sills in the volcanic rocks near Dogtown, just north of the Angels Camp quadrangle, and in the Mariposa formation in the southern part of the Angels Camp quadrangle and northwestern part of the Sonora quadrangle. The feldspar porphyry is dark gray-green and contains light-colored phenocrysts of altered feldspar up to half an inch long. The rock is massive and has not been sheared, but locally is well jointed. The texture is generally diabasic and the rock therefore has been mapped as porphyritic diabase.

Diabase

Altered dikes of dark greenish-black diabase intrude marble of the Calaveras formation and are well exposed in road cuts along State Highway 49 just north of Sonora. Because of the strong contrast in the color of the two rocks the dikes are sharply defined. Similar dikes occur in the schist of the Calaveras formation, but most of them are too small to be shown on the geologic map. Moreover, where fresh the dikes in schist are not readily discernible, as the color of the two rocks is nearly identical. However, the dikes generally weather to a much deeper red-brown than the country rock.

Hornblende Lamprophyre

In the Angels Camp quadrangle a dike of hornblende lamprophyre has been mapped in the northeast part of the quadrangle, and a small mass of similar rock occurs in the body mapped as ankerite-talc schist 2 miles due east of Angels Camp, where it is associated also with actinolite schist and talc schist. The lamprophyre is a fine-grained dark-green rock consisting essentially of brownish-green hornblende phenocrysts in a matrix of albite, pale chlorite, epidote, and pale actinolite or tremolite.

Altered Quartz-bearing Intrusive Rocks

Altered quartz-bearing intrusive rocks occur in a few places in the Angels Camp quadrangle. Granodiorite has been mapped near the southwest corner of the quadrangle, just south of the Vallecito Western mine, and in a small body 2½ miles north of the southwest corner; and muscovite granite has been mapped just northwest of the Vallecito Western mine.

Age

The evidence on the age relations of the intrusive rocks within the mapped area is inconclusive. We know that some of the intrusives cut Jurassic rocks and we have no reason to suppose that any of them are different in age. Possibly the intrusion took place in Late Jurassic time or later, beginning with peridotite and ending with the more acidic facies. Later studies may show that some of the intrusives of the Mother Lode area are hybrids, especially those emplaced in greenstones.

In the mapped area fresh intrusive rocks are not exposed. In the hope of shedding some light on the problem of the age relations of the altered intrusive rocks to the fresh rocks of the Sierra Nevada batholith, thin sections were made of fresh-looking intrusive rocks. Specimens were taken from the main part of the batholith several miles west of Yosemite National Park, and from the intrusive rock just east of the Sonora quadrangle, which apparently is a lobe of the main batholith. The intrusive rocks from west of Yosemite Park are fresh and unaltered. The intrusive rocks from the vicinity of Sonora, though appearing fresh, are seen in thin section to be considerably altered; feldspar has been largely saussuritized and hornblende has been partly converted to chlorite. Thus, extensions of the main batholith are altered to about the same extent as the mafic rocks. This suggests only that the altered intrusive rocks of the mapped area are not necessarily older than the fresh intrusive rocks of the main mass of the batholith.

If the intrusive rocks of the Mother Lode region are of approximately the same age as the batholithic rocks to the east, the conclusion is unavoidable that the low-grade metamorphism, characteristic of most of the rocks of the region, was not caused by the intrusion of magma. The development of chiastolite in the schist near the southeast corner of the Sonora quadrangle probably was caused by the intrusions; but the saussuritization and uralitization of nearly all the rocks must have some other causes, such as late dislocation and shearing. Dynamometamorphism continued in the mapped area after the intrusive rocks were emplaced.

STRUCTURE

Structurally, the mapped area is characterized by northwesterly strikes of beds and foliation, parallel to the trend of the Sierra Nevada; steep northeasterly dips; overturned, nearly isoclinal, major folds; and longitudinal reverse faults.

Folds

The minor folds are more evident than the regional folds within the map-area, for the former can each be seen within the limits of one outcrop whereas the latter are largely inferred from the areal patterns made by the rock units. So far the major folds have been more useful than the minor folds in deciphering the structure of the area. Within the Angels Camp quadrangle regional folds are interpreted for the area southwest of the main Mother Lobe belt but in the Sonora quadrangle the inferred regional folds are northeast of the Mother Lode belt. This indicates that folding is probably the common thing rather than the unusual and would occur more often on geologic maps of the region but the lack of good exposures and conclusive field evidence.

Major Folds

The traces of the axial planes of the more prominent major folds are shown on the geologic maps (pls. 1 and 2) and on the structure maps (figs. 7 and 8). The evidence for many of the mapped folds is good, but in some places folds have been inferred in order to make a more reasonable interpretation of the structure. In parts of the chlorite 2 subzone, for example near Jamestown, the interpretation of anticlines and synclines is based on the assumption that phyllite and related rocks underlie the rocks of the green schist. If this assumption is incorrect, and if the rocks of the green schist underlie the phyllite, then the anticlines, as mapped, actually are synclines, and the synclines are anticlines. In general the major folds are nearly isoclinal and are overturned to the southwest with both limbs dipping 65°-85° NE.

Bear Mountain, in the southwest part of the Angels Camp quadrangle, is structurally a series of anticlines and synclines, generally plunging about 5°-10° SE. At the south end of Bear Mountain the angle of plunge of one of these folds steepens to an average of 20°; locally, plunges as steep as 40° have been measured. Southwest of Bear Mountain is another group of major folds, some of which plunge gently northwest.

The rocks of the region north, northeast, and east of Bear Mountain probably have been intensely folded, but in large parts of that area the structure is so complicated by faults and shear zones that the presence of major folds cannot be demonstrated with certainty, and the folds shown in cross section on plate 3 in that area are largely inferred.

In the southeast part of the Sonora quadrangle, an area of intrusive rock occupies, in part, a major anticline. Schistosity and bedding in the surrounding metamorphic rocks bend around and parallel closely the edge of the intrusive body, showing that the intrusion of the gabbro was responsible for the bending of the surrounding rocks, or that post-intrusion deformation took place. However, the presence of cross-cutting relationships and of several roof pendants of schistose rocks indicates that not all the country rock was pushed aside. In the southwest part of the Angels Camp quadrangle small bodies of intrusive rocks similarly occupy the cores of anticlines, but in this area, although the intrusive rocks seem to have been localized by the anticlines, no further bending has occurred.

Minor Folds

In addition to the major gently plunging folds revealed in regional mapping, the mapped area also contains many minor steeply plunging folds that can be seen in outcrops or groups of outcrops. These small folds generally plunge 40°-60°, although some have vertical axes. Most of the minor folds are believed to be drag folds associated with some of the faults and regional shear zones, and did not prove to be an aid in deciphering the major folded structure. For example, two small folds on the limbs of a major syncline in secs. 2 and 11, T. 2 N., R. 12 E., just southeast of Elkhorn Station in the Angels Camp quadrangle (pl. 1), plunge 50° and 40° N., although the major syncline plunges gently, probably about 10°, southeast. The patterns of many of the drag folds suggest, as do the patterns of the offsets along faults, that the rocks to the east have moved upward and northward with respect to those to the west.

Faults

A major zone of faults having, in general, reverse movement, and called the Mother Lode fault system, extends across the mapped area (pls. 1 and 2) in a northwesterly direction. Reverse faults have been recognized in this region for many years. Ransome (1900, p. 8), although he did not map any of these faults, recognized the fact that the quartz veins of the Mother Lode occupied faults. In the present investigation an attempt has been made to map all known faults. In so doing it has been necessary to generalize considerably, especially along the mineralized zones, because in many places the faults are so closely spaced that, even on a scale as large as 2,000 feet to the inch, they cannot all be shown. In some areas, for example, the northeast part of the Angels Camp quadrangle and near Jackass Hill in the Sonora quadrangle, exposures are so poor that mapping of faults is not practicable; field data suggests, however, that in these areas faults not only are present but are abundant.

Mother Lode Fault System

The Mother Lode fault system is a major zone of anastomosing reverse faults and shear zones extending in a continuous belt northwestward from south of the town of Mariposa, Mariposa County (Cloos, 1932), at least as far as the vicinity of Georgetown, El Dorado County, a distance of about 120 miles (fig. 1 and pls. 3 and 4). Gold-bearing quartz veins occur at intervals along this system of faults and, according to Fairbanks (1890, pp. 23-24), the series of veins was given the name "Mother Lode" by miners and prospectors during 1850 or 1851.

In the Chinese Camp quadrangle, about a mile south of the south border of the Sonora quadrangle, the Mother Lode fault system may be said to consist of only one major fault zone. At the south border of the Sonora quadrangle the fault system is a shear zone ranging in width from 300 to 600 feet. Farther northwest, near Sullivan Creek, the fault system begins to branch and diffuse, and in the vicinity of Jamestown attains a width of about 2 miles. In the Angels Camp quadrangle, near Angels Camp, the fault system is between $2\frac{1}{2}$ and $2\frac{3}{4}$ miles wide.

The "Main Fault" of the Mother Lode System. Ransome (1900, p. 9), in his discussion of the Mother Lode veins, states, "It is customary among the miners to distinguish one single vein as '*the Mother Lode.*' Not only does such a terminology lead to endless and unprofitable discussion, but, in the light of what is known of the complex character of the Mother Lode, the restriction of that name to any single vein of the system is misleading." Where he discusses the veins of the Mother Lode, Knopf (1929, p. 5) agrees with Ransome concerning this idea, yet where Knopf writes of the faults of the Mother Lode, rather than the veins, he distinguishes a single main or master Mother Lode fault (1929, p. 46). Evidently Knopf's "main fault" is the fault along which rocks of very low metamorphic grade (chlorite 1 subzone) on the footwall side have been brought into juxtaposition with rocks of slightly higher metamorphic grade (chlorite 2 subzone) on the hanging-wall side.

Thus, in the Sonora quadrangle, this main fault would correspond to the chief mineralized fault and would lie along the central part of the Mother Lode fault zone; in the Angels Camp quadrangle the main fault would be well to the west of the chief mineralized faults and would lie along the western part of the fault zone; whereas still farther to the northwest, beyond the mapped area, the main fault would be east of the chief mineralized fault.

Zone of Intense Faulting

Two elongate strips along the Mother Lode fault system, one in the south part of the Sonora quadrangle and one in the northwest part of that quadrangle and the southeast part of the Angels Camp quadrangle, contain outcrops of marble and other rocks mapped as Cala-

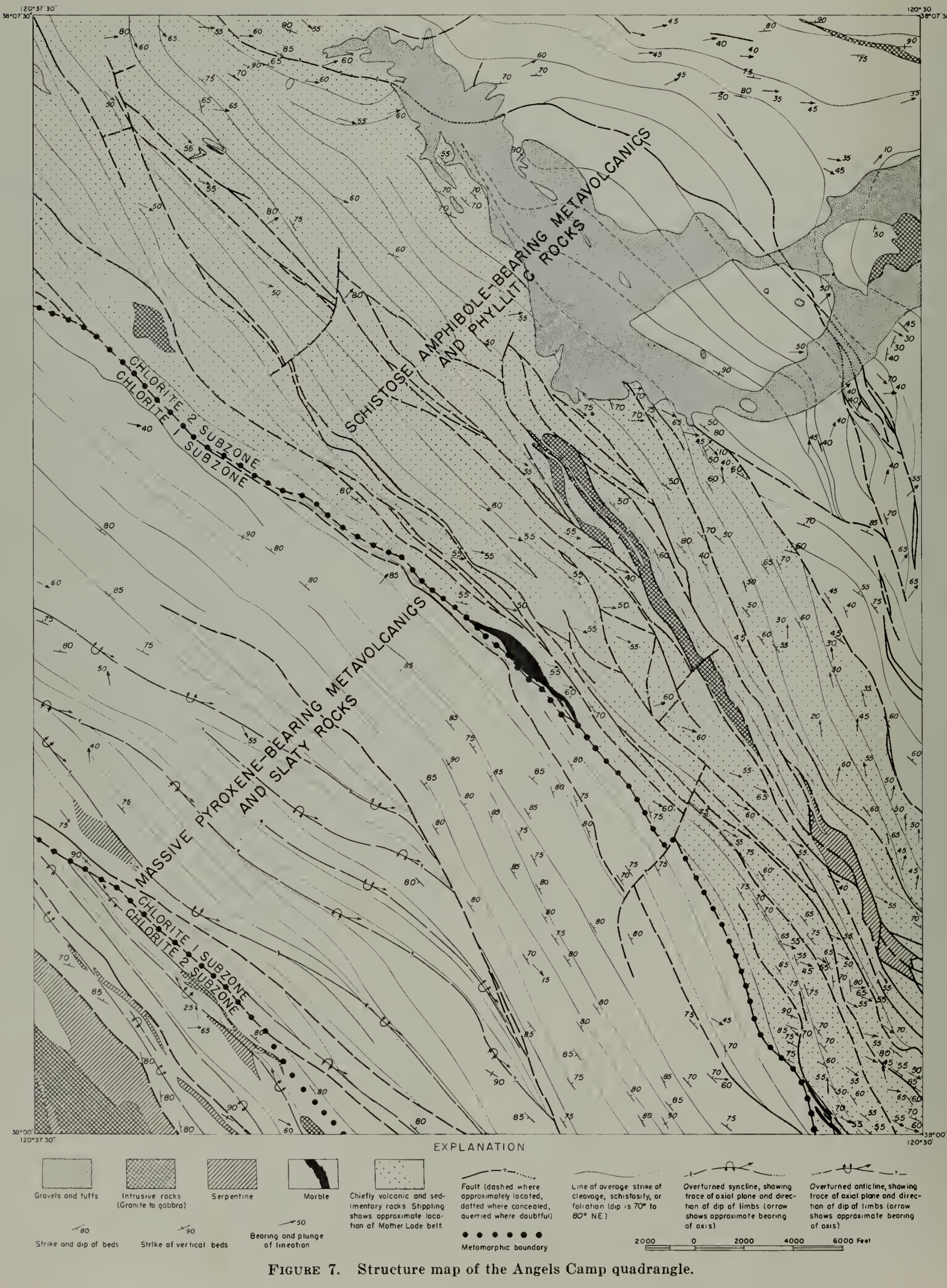

FIGURE 7. Structure map of the Angels Camp quadrangle.

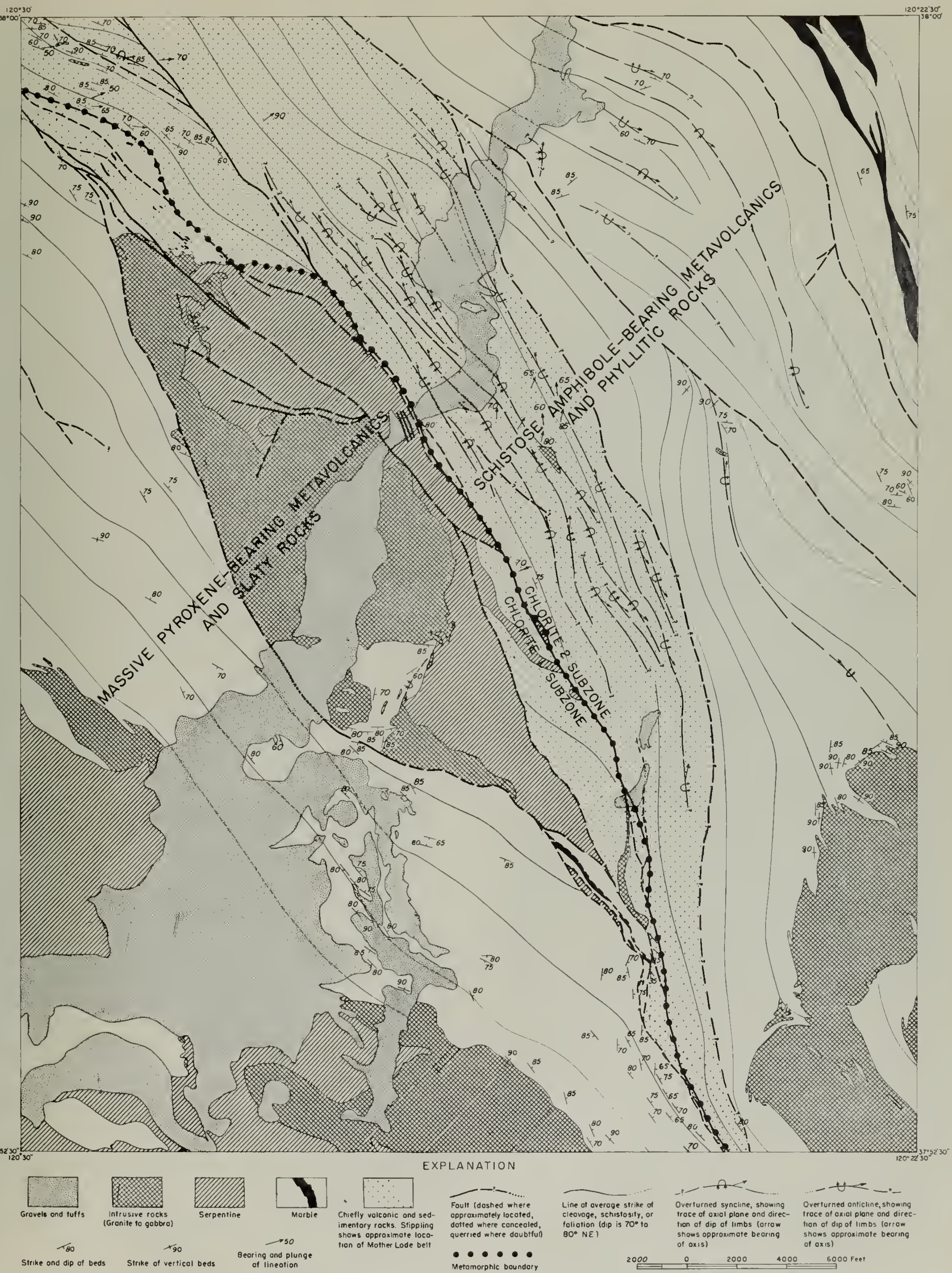

Figure 8. Structure map of the Sonora quadrangle.

veras formation. These rocks occupy a zone of intense faulting and shearing along the Mother Lode belt. Within this zone, rocks of various kinds and from different stratigraphic horizons are brought into juxtaposition; along the eastern edge of this zone are rocks of a higher metamorphic grade than those on the western edge.

In the southern part of the Sonora quadrangle the zone of intense faulting is relatively narrow and comprises the total width of the Mother Lode fault system. Here, rocks of the Calaveras formation, chiefly marble; Cosumnes formation; Logtown Ridge formation; and pods of serpentine are brought into close association by faults. These rocks are bounded on the west by the Mariposa formation and on the east by the rocks of the green schist of the chlorite 2 subzone. To the northwest the Mother Lode fault system becomes diffuse and widens, but a zone of major shearing and faulting, although somewhat wider and less well defined, can be traced northwest across the quadrangle. In the central part of the quadrangle the large serpentine intrusive body absorbs much of the faulting, but zones of sheared and slickensided serpentine mark the trend of the fault zone.

In the northwest corner of the Sonora quadrangle, rocks of the Calaveras formation are in fault contact with the Mariposa formation on the west and with Cosumnes formation on the east, and where exposed exhibit great shearing and crushing, with the development of tectonic breccia. Exposures in this area are poor and it is probable that if better exposures existed the mapping would likely reveal juxtaposed fault-bounded blocks from several formations rather than a narrow continuous belt of highly sheared Calaveras rocks. Evidence indicating that this interpretation may actually be true is furnished by exposures along the Stanislaus River just beyond the northwest corner of the Sonora quadrangle. In this area, which is a continuation of the same zone of faulting, lenses of marble, in places associated with phyllonite (?) and tectonic breccia (Calaveras formation), are in fault contact with rocks of the Cosumnes, Logtown Ridge, and Mariposa formations as well as with a body of serpentine. The rocks of these formations occur in angular-shaped bodies ranging in length from a few hundred feet to almost 2,000 feet.

Locally marble lenses consist not of one body, but rather of a main lens with many smaller fragments distributed around it, as may be seen at low water along the north bank of the Stanislaus River in the southeast corner of the Angels Camp quadrangle. The marble is completely crystalline and has a medium to coarse-grained xenomorphic texture. Sharp minor flowage folds in the main lenses of marble, as well as the presence of the smaller adjacent fragments of marble, suggest the possibility that in some places the marble was injected upward along the intensely sheared and faulted zone. Heyl (1947) referred to the limestone (marble) bodies of this sort as "piercement structures."

Lindgren (1900, p. 2), in discussing the occurrence of a fossiliferous body of limestone of Paleozoic age along the contact between two formations of presumed Jurassic age in the western part of the Colfax quadrangle, suggested that the limestone was a fragment torn loose from its proper position during a period of eruption.

Evidence for Faults

In general, the faults strike approximately parallel to bedding, cleavage, and schistosity, but most of the faults dip more gently than these features. Many faults bound rock units, but some have the same wall rock on both sides. Because of this parallelism or subparallelism with other structural features, faults in places are difficult to recognize. The following criteria have been found useful for the recognition of faults and shear zones.

(1) Truncation of rock units.
(2) Truncation of major folds.
(3) Truncation of average strike of cleavage, schistosity, foliation; see figs. 7 and 8.
(4) Presence, along narrow belts, of horses of several kinds of rock from different stratigraphic horizons.
(5) Presence of quartz veins.
(6) Presence of zones of hydrothermally altered rock.
(7) Presence of slickensides and mullions.
(8) Presence of brecciated and mylonitized rock.
(9) Presence of small marble lenses.
(10) Presence of drag folds.
(11) Displacement of rock units.
(12) Development of schistosity in normally massive rocks.
(13) Presence of springs and water seepages.

Obviously, few of these criteria can be used alone as evidence for a fault, but faults have been indicated on the map where several of the criteria suggest their presence.

Much of the evidence for faults is indirect. Large continuous quartz veins, for example, are found to occupy faults or fault zones in underground workings; the outcrop of such veins, therefore, is taken to be a good indication of the presence of a fault. Where exposures are particularly good, as along the Stanislaus River and Mormon Creek, many small lenses of marble are found to be associated with faults and shear zones; and although the presence of small lenses of marble ordinarily would not constitute evidence for faulting, in this area it is regarded as suggestive of faulting.

Faults Outside the Mother Lode System

Most of the faults that have been mapped belong to the Mother Lode fault system, but a few faults lie outside that belt.

In the Angels Camp quadrangle several faults occur east and northeast of the Mother Lode fault system and are evidenced largely by more intense shearing, by quartz veins, and by peculiar hydrothermally altered rocks such as calcite-muscovite-chlorite rock and ankerite-talc schist. Southwest of the Mother Lode fault system is a second area of faults. One of these faults truncates the folded structure of Bear Mountain; it is a reverse fault along which younger rocks have been thrust over older ones. Gold mines and prospects are rare along the faults that lie outside the Mother Lode fault system.

In the Sonora quadrangle only three faults have been mapped outside of the Mother Lode fault system and two of these are in the northeast part of the area. One of these faults lies about midway between Jamestown and Sonora and is questionably located along part of its length; in fact, possibly it may die out toward the north. Directly east of Jamestown, however, its position is established where it truncates both rock units and a major north-plunging anticline. A third fault outside of the Mother Lode fault system is near Melones Reservoir in the west part of the Sonora quadrangle, where the Mariposa formation is thrust over the Logtown Ridge formation; these structural relations are similar to those along the eastern foot of Bear Mountain in the Angels Camp quadrangle, where the Mariposa formation is thrust over the Logtown Ridge formation, and very likely this fault extends northwestward to Bear Mountain.

These faults and fault zones, which in the relatively small area mapped appear to be outside of the Mother Lode fault system, may, of course, actually join the system beyond the boundaries of the mapped area.

Displacement on Faults

The total displacement on the major faults of the Mother Lode system is uncertain. Some of the faults clearly have undergone more than one period of movement, and late normal displacement is known to have occurred on some of the reverse faults. Dips on faults ranging generally from 55° to 70°, can be observed but no measure of the displacement could be obtained at these places. One fault, about a mile southwest of Angels Camp, has a horizontal separation (Billings, 1942, p. 145), parallel to the trace of the fault, of nearly 3,000 feet, measured between the offset parts of a band of phyllite, but the net slip, of course, may be much less. Knopf (1929, p. 25) reported that in some of the mines in Amador County, northwest of the mapped area, the apparent displacement on reverse faults, measured "in the plane of the dip," ranged from 120 to 375 feet; he also reported that a horizontal component of 120 feet was measured. Dip slip, strike slip, and net slip, however, were not calculated.

In most places the relative movement has been reverse. However, criteria for determining the direction of movement along faults in this area are confusing and, as stated above, there is evidence for more than one period of movement. Such features as drag folds, slickensides, chatter marks, juxtaposition of beds of different age, and offset of beds, although generally indicating reverse movement with a major vertical component and some horizontal component (east side moved north relative to west side), locally suggest strike-slip movement and, in a few places, normal dip-slip movement.

Periods of Faulting

At least four periods of faulting have occurred in the mapped area. In the Angels Camp quadrangle, south of Angels Camp, longitudinal faults have been offset along transverse faults and these in turn have been offset along longitudinal faults. Much more recently the latite lava flow and the underlying volcanic rocks and gravel of Table Mountain, Sonora quadrangle, have been offset by normal faults along which the east or hanging-wall side has dropped relative to the west side, with a displacement on one fault of 75 to 100 feet; this late normal movement took place along some of the much older reverse faults of the Mother Lode system.

The north end of the large mass of serpentine and gabbro west of Jamestown shows in detail a typical intrusive pattern where it injects sheared Calaveras formation. This pattern indicates intrusion of the mass along or into a pre-existing zone of shearing. Subsequently, movement along this fault zone locally offset the intrusive rocks. A small protrusion along the west side of the gabbro body, west of Jamestown, furnishes evidence that supports this idea. The small bulge of gabbro seems to have an intrusive contact with the Mariposa formation, whereas the main mass of gabbro has a sheared or faulted contact with the Mariposa. This shear zone, or fault, instead of diverging around the small bulge, passes through it, with the usual development of quartz veining and shearing, which indicates that some post-intrusive movement has taken place along that fault.

Post-intrusive movement also has taken place along other faults of the Mother Lode system, especially along the east boundary of the serpentine mass west of Jamestown, as evidenced by considerable shearing of the serpentine. Small bodies of ankerite-talc schist containing many quartz veins and in places having a green color owing to the presence of mariposite [12] occur within the fault near Quartz Mountain, Stent, and Rawhide, and probably were derived primarily from highly crushed and altered serpentine. In the vicinity of Carson Hill and Angels Camp small bodies of serpentine and gabbro have been intensely sheared along some of their faulted contacts.

Age of Faulting

The periods of faulting described above cannot be closely dated. The Mother Lode fault system, as well as the other main faults in the mapped area, formed in Late Jurassic or Early Cretaceous time during the Nevadan orogeny. Most, if not all, of the faulting probably took place after the main folding, for folds have been truncated by major faults; and no folded faults have been mapped, although that does not preclude their existence. Some of the faulting preceded the intrusion of ultramafic and mafic rocks, for these rocks have been injected into shear zones, and the positions of some of the intrusive bodies appear to have been determined in part by pre-existing faults. Cloos (1932) has suggested that some of the faulting occurred during the intrusion of the batholith of the Sierra Nevada. Some of the faulting followed the intrusion of the mafic and ultramafic rocks, for in places these rocks have been sheared and offset with considerable apparent horizontal displacement. Some of the faulting followed the formation of some of the quartz veins, for in the northernmost accessible underground workings of the Melones adit (fig. 9), vein quartz has been mylonitized and crystals of pyrite in the quartz have been sheared and rounded. Normal faulting followed the formation of the latite of Table Mountain, which probably is late Pliocene or early Pleistocene in age.

In summary, movement along faults in the mapped area has occurred at least four times and probably more. Movement has not always been constant in direction, especially along the Mother Lode fault system. Although reverse movement with some horizontal component is indicated on most of the faults, strike-slip as well as normal movement also has taken place.

Cleavage and Schistosity

Most of the rocks in the mapped area are foliated, the chief exceptions being the more massive intrusive rocks

[12] Prof. C. O. Hutton of Stanford University has reported orally the finding of minute crystals of pale-violet to colorless tourmaline within the ankerite-talc schist.

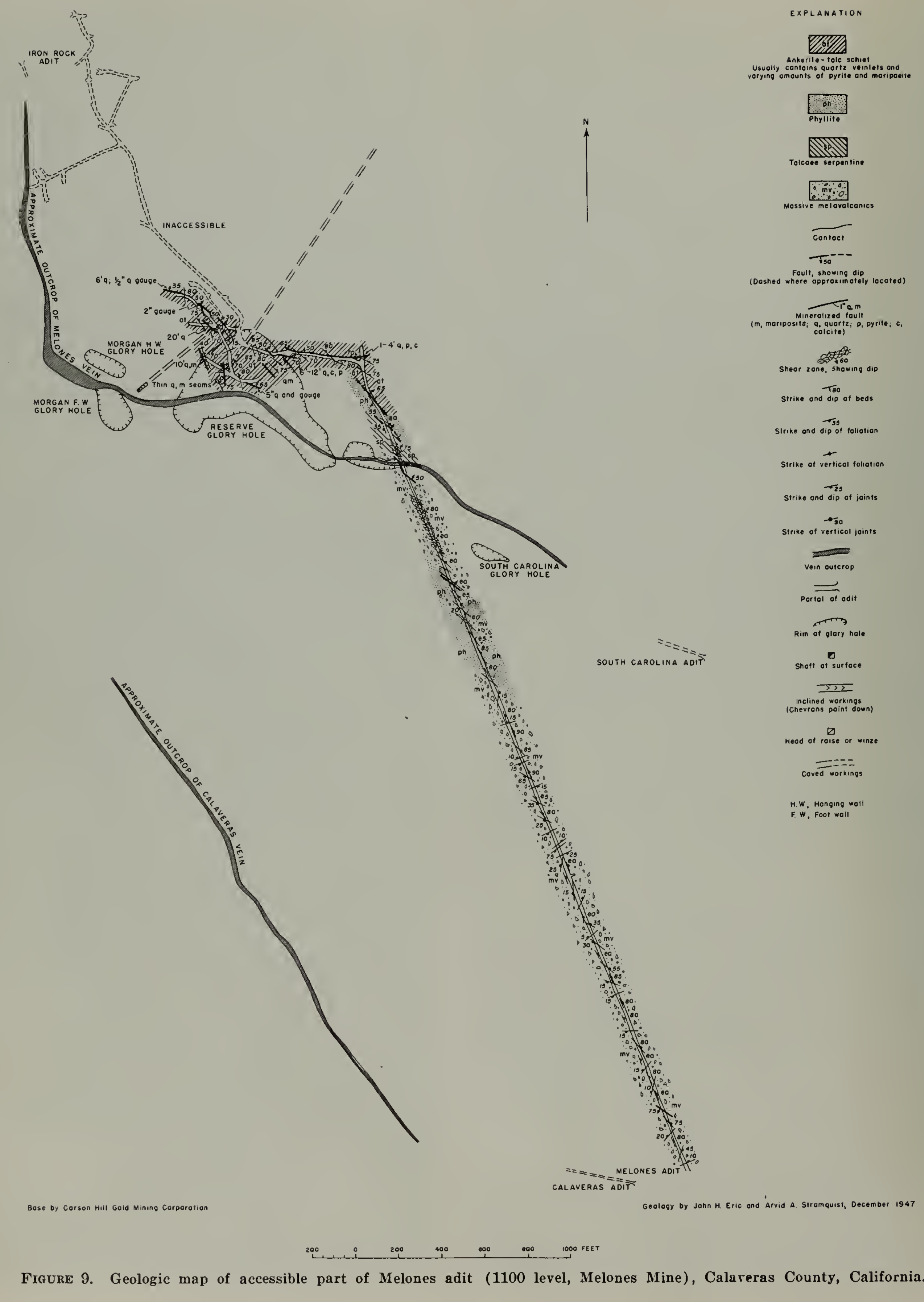

FIGURE 9. Geologic map of accessible part of Melones adit (1100 level, Melones Mine), Calaveras County, California.

and the coarse volcanic breccia of the Logtown Ridge formation. In general, schistosity is developed in the rocks of the chlorite 2 subzone, whereas cleavage prevails in the rocks of the chlorite 1 subzone (Billings, 1942, p. 213). In the more massive parts of the Logtown Ridge formation the foliation generally is very crude fracture cleavage and resembles jointing; that this jointing is incipient cleavage or schistosity is suggested by the fact that the joints are parallel to the regional trend of cleavage and schistosity in other rocks.

Cleavage in the chlorite 1 subzone is best developed in the argillaceous rocks of the Mariposa formation. Some of the slates of the Amador group possess good cleavage, but as they generally contain more tuffaceous and sandy material, the cleavage is usually less well developed than in the slates of the Mariposa formation. Except along the noses of plunging folds, cleavage and bedding generally are approximately parallel. In the chlorite 2 subzone, schistosity is due chiefly to the orientation of chlorite and actinolite in the rocks of the green schist series and to the orientation and banding of mica plates in the phyllitic and quartzose rocks.

In parts of the mapped area a somewhat later shear cleavage has been superimposed on the more common schistosity and slaty cleavage. The shear cleavage is represented by joints, generally 1 to 10 mm apart, along which the rocks have been sheared. The amount of shearing on any one plane rarely exceeds 1 mm, but inasmuch as there may be hundreds of these planes in a single outcrop the total displacement may be considerable. Shear cleavage is most common in the phyllites within and east of the Mother Lode fault system, but is also found in the slates of the Mariposa formation to the west. The shear cleavage generally strikes more northerly and dips more steeply than bedding and slaty cleavage. The intersection of the two cleavages produces steeply plunging crenulations and the rock may break into angular elongate fragments; such rocks have been called pencil slates. That shear cleavage represents an important phase of the deformation of the area is shown by the fact that in many places this cleavage is approximately parallel to the axial planes of small minor folds. Moreover, where shear cleavage is present, the long and intermediate axes of stretched pebbles in the conglomerates lie in the planes of shear cleavage.

Joints

True joints, as distinguished from incipient schistosity and from shear cleavage, are found particularly in rocks of the lowest metamorphic grade. The larger intrusive bodies and the coarser-grained rocks of the Logtown Ridge formation, in which cleavage and schistosity are absent or incipient, are especially well jointed. Most of the joints dip 70° to 90° and many are slickensided, but we are uncertain whether the slickensides originated during the formation of the joints or are the result of later movement along joint planes. In places joints have the same attitude in the massive intrusive rocks as they do in adjoining argillaceous and volcanic rocks, and locally they even cross the contacts, which suggests that the joints are chiefly younger than the igneous rocks and not contemporaneous with them. Some of the transverse joints on Bear Mountain appear to be approximately perpendicular to the axes of the major folds.

Lineation

The linear elements in the mapped area include (1) fold axes, (2) long axes of stretched fragments in both clastic and pyroclastic rocks, (3) intersections of planes, chiefly bedding, schistosity or cleavage, and shear cleavage, (4) crenulations due to minute displacements along planes of shear cleavage, and (5) slickensides and mullions on faults and quartz veins.

With the exception of major fold axes and some of the slickensides and mullions, most of the lineations plunge rather steeply, and are probably related to the later, relatively minor deformation that produced drag folds and shear cleavage. Most of the lineations plunge southeast or east; however, north- and northeast-plunging lineations are abundant northeast of the fault that passes just east of the village of Carson Hill, as shown on figure 7 and plate 1.

Stretched Pebbles and Fragments

The amount of stretching of pebbles in the conglomerates and of blocks and bombs in the volcanic breccias and agglomerates varies considerably from place to place. No appreciable stretching is evident in most of the rocks of the chlorite 1 subzone. In the coarse-grained rocks of the chlorite 2 subzone the amount of stretching ranges from incipient to great. Pebbles in the conglomerates just west of Carson Hill and southeastward into the Sonora quadrangle have axial ratios as great as 1:2:20, but, on the average, the long axes are four to six times as long as the short axes. The long and intermediate axes lie in the planes of schistosity or shear cleavage (if present), the short axes perpendicular to these planes. Most of the long axes plunge 35° to 70°, and the average plunge is about 55°.

Associated with some of the conglomerates and phyllites are thin-bedded cherts which in places have been broken into fragments. The long axes of the fragments are parallel to the long axes of stretched pebbles and to the axes of small folds.

Intersections and Crenulations

In the mapped area lineations commonly have been produced by the intersections of bedding, schistosity or cleavage, and shear cleavage. Inasmuch as bedding and schistosity or cleavage are about parallel at many places, and because shear cleavage is approximately parallel to the axial planes of minor folds where such folds are present, the lineations produced by intersections generally plunge, on the average, about 55°, parallel to the axes of the minor folds. In places the lineations are weak, in others, particularly areas underlain by phyllite, they are sufficiently intense to give the rocks a pencil structure. Slight movements along planes of shear cleavage have produced small crinkles or crenulations on these planes. The resulting lineations plunge parallel to the axes of minor folds and parallel to the long axes of stretched fragments.

Lineations on Faults and Quartz Veins

Lineations produced by slickensides, mullions, and intersections are present along faults and on quartz veins associated with faults, and may be seen readily on Carson Hill. At the Santa Cruz open cut of the Calaveras mine, mullions on the hanging wall of the bull quartz plunge 55° E. or SE. They have a wave length of about a foot and an amplitude of about 2 inches. Some of the mullions have an axial plane jointing that strikes east or southeast and dips 70° S. In places the joints are more conspicuous than the mullions, and thus the lineation may be caused by the mullions, by the intersection of quartz and joints, or by the intersection of mullions and joints.

In the Finnegan open cut, which is now the northern part of the Reserve glory hole of the Melones mine, broad, open rolls are present in the schistosity planes. The rolls plunge about 25° NW., and "flat" veins of quartz, ankerite, and pyrite, striking north and dipping 35° W., fill faulted fissures parallel to the axial planes of the rolls. Movement along these fissures is reverse, and broken planes of schistosity are displaced as much as 1 inch.

In the Reserve glory hole, which extends from the Finnegan mine southeastward nearly to the top of Carson Hill, the intersection of "flat" veins, 1 inch to 4 inches thick, with the bull quartz or with the wall parallel to the bull quartz, produces a lineation on the wall that plunges 0° to 15° NW. At the northwest end of the Reserve glory hole is a 1-foot vein on a smooth footwall (presumably a fault) that strikes N. 20° W. and dips 35° E. Many joints or fractures are parallel to this vein, and their intersection with the north wall of the glory hole gives an east-plunging lineation.

At least three types of lineation are readily visible in the Morgan glory hole. According to Mr. Harry T. Libby,[13] Superintendent at Carson Hill, the mine commonly known as the Morgan mine consists, on the surface, of two glory holes, separated by the bull quartz; the footwall hole is the Morgan glory hole, and the hanging-wall hole is the Union or Morgan hanging wall. On the footwall of the Union mine are joints that strike N. 20° W. and dip 40° W. The intersection of these joints and the bull quartz, or the wall parallel to the bull quartz, gives a lineation, also marked by broad, open rolls similar to those at the Santa Cruz open cut, that plunges north at angles of 25° to 30°. A second, much finer-textured lineation is produced by the intersection of the bull quartz and a system of closely spaced joints that strikes N. 70° E. and dips 75° S. This intersection gives a lineation plunging about 50° S.

PETROLOGY AND METAMORPHISM

Before discussing the petrology of the various rock types and the metamorphic changes of a structural and mineralogic nature that have taken place, a brief discussion of the metamorphism in the district is desirable.

Nearly all the pre-Tertiary rocks in the mapped area are dynamo-metamorphic types belonging to the chlorite zone of metamorphism. Only the flat-lying rocks of Tertiary age, which form a thin discontinuous cover on the pre-Tertiary rocks, are nonmetamorphic.

The pre-Tertiary rocks of the chlorite zone have been subdivided, on a structural and mineralogic basis, into two subzones. In general the rocks lying to the west of one of the major Mother Lode faults, which forms the metamorphic boundary or isograd between the subzones, are only slightly altered and have been assigned to the chlorite 1 subzone. Their original textures and structures, and some of their original minerals, are still largely retained. To the east of the metamorphic boundary the rocks have been considerably more altered and, as a result of more intense stress, schistose structures have developed. These rocks have been assigned to the chlorite 2 subzone; they are largely reconstituted mineralogically and only a few relict minerals and textures remain. Locally, the incipient segregation of mineral components into bands gives the rocks a crude secondary layering or foliation. A small area in the southwest part of the Angels Camp quadrangle has been assigned to the chlorite 2 subzone and, in addition, several small "pods" of less metamorphosed rocks, not mapped, occur in the main part of the chlorite 2 subzone—one of these "pods," for example, is in the syncline near the northwest corner of the Sonora quadrangle.

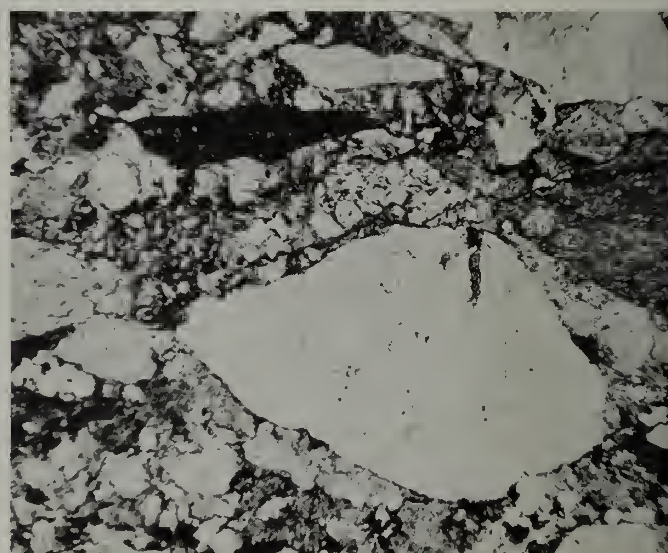

FIGURE 10. Photomicrograph of grit member from the Mariposa formation. (X25) Composed largely of angular to sub-angular grains of quartz, chert, quartzite, quartz-mica schists, with occasional grains of volcanic rocks.

Hutton and Turner (1936; Turner, 1948, p. 38) have described four subzones of the chlorite zone based on metamorphism of graywacke. In the mapped area, metamorphosed graywacke makes up only part of the lithologic units, and the bulk of the rocks tends toward more extreme compositions—on the one hand a great deal of mafic volcanic material and of mafic and ultramafic intrusive material, and on the other hand much argillaceous and quartzose material. However, despite the relative scarcity of graywacke, a twofold subdivision of the chlorite zone has been made, based on structural and mineralogic features. The mafic rocks are sufficiently closely associated with the pelitic rocks so that grade of metamorphism can be fairly well established. Because of the relative scarcity of graywacke, the two subdivisions of the chlorite zone, as used in this paper, do not necessarily correspond to the same units in Hutton and Turner's classification.

Rocks of the Chlorite 1 Subzone

The rocks of the chlorite 1 subzone characteristically show either no schistosity or very crude schistosity, the only exceptions being in the immediate vicinity of

[13] Libby, H. T., oral communication.

faults. Slates and fine-grained silty rocks of the Mariposa formation and Amador group have developed fair to good slaty cleavage, but the coarser-grained sedimentary rocks and the intrusive bodies are generally massive and have a fairly well developed jointing. In thin section, most of the rocks are seen to have been crushed and reconstituted mineralogically, but some original textures and structures are retained. Most of the plagioclase has been saussuritized, but much of the primary pyroxene in the volcanics has persisted without perceptible alteration.

Quartzose and Argillaceous Rocks

The quartzose and argillaceous rocks of chlorite 1 subzone consist of conglomerate and grit, dark and light gray slate, coarse to fine grained graywacke, and fine grained tuffaceous sandstones and siltstones.

Grit and Conglomerate. Narrow layers of grit with beds of pebble conglomerate occur in the dark-gray slate of the Mariposa formation. These layers are composed largely of quartzose material.

The grit and pebble beds consist primarily of subangular grains of quartz; pebbles, up to about 1 inch in diameter, of vein quartz, quartzite, chert, and quartz-mica schist; a few angular fragments of porphyritic andesite; scattered crystals and fragments of plagioclase, partly altered to sericite; and clots of a negative chlorite, possibly pseudomorphous after pyroxene (fig. 10). These mineral and rock particles are embedded in an argillaceous matrix that has been considerably sheared, with the development of sericite and chlorite. Many of the quartzose grains have been crushed along their edges, and mortar structure has been developed. Abundant minute grains of magnetite and scattered grains of leucoxene occur chiefly in the sheared matrix between the larger components of the rock.

In composition, the grit and conglomerate layers are essentially the same, the chief difference being that the grit is finer grained and has a more uniform texture. It also has a slightly higher percentage of quartz grains than the conglomerate, although the two rocks grade into each other with no definite contact.

The grit and conglomerate have undergone only very slight mineralogic changes, and, except for shearing of the fine-grained matrix and some crushing of the larger grains along their edges, the original texture has been retained. The rock generally is well bedded and massive, although locally the shearing between component grains, or fragments, has produced a crude cleavage.

Associated in part with the beds of grit and conglomerate is a unit of slightly more mafic clastic rock that contains a higher percentage of plagioclase, numerous slate fragments, and a few angular fragments of mafic volcanic rocks embedded in a fine-grained chloritic and sericitic matrix. This unit has the composition of graywacke as defined by Pettijohn (1949, pp. 243-250), and has been mapped as such.

Slate. Slate occurs in both the Amador group and the Mariposa formation; the slate of the Mariposa formation is somewhat darker.

The slate of the Cosumnes formation is gray and the diameter of its component grains averages about 0.025 mm. The principal minerals are detrital quartz in subangular grains, feldspar (probably albite), and crystalloblastic muscovite. The muscovite plates are fairly well oriented and evenly distributed throughout the rock; there is no tendency toward segregation into bands. In addition to the principal minerals, small crystals of calcite, oxidized pyrite, and magnetite are present in minor amounts.

Slate of the Mariposa formation is very dark lead gray to nearly black. Its grain size averages about 0.025 mm. The chief recognizable constituents are angular quartz grains, muscovite flakes, sericite, and feldspar that ranges in composition from albite to sodic oligoclase. The feldspar in most places has been somewhat saussuritized, although in a few places it is unaltered. A great deal of black opaque carbonaceous material accounts for the very dark color of the slate.

The slates of both the Cosumnes and Mariposa formations contain abundant grains of quartz and feldspar of silt size, and possibly there is no true "clay slate" anywhere in the area.

Tuffaceous Rocks. Fine-grained tuffaceous sandstone and siltstone are common in the Cosumnes formation. They consist largely of plagioclase in anhedral to subhedral grains, subangular quartz grains, scattered rounded grains of chert or chalcedony, fresh to slightly altered grains of augite, and a few irregular-shaped patches of a light-green chlorite with deep-blue anomalous interferences colors, possibly pseudomorphous after tachylyte. These component mineral and rock fragments have an average grain size of about 0.1 mm and are embedded in a very fine-grained light-colored semi-opaque matrix of argillaceous or volcanic material that seems now to be in part sericite and chlorite. Interstitial calcite is common, and some of the crystals are up to 0.1 mm in diameter; the larger calcite crystals appear to be filling pores in the rock.

These tuffaceous rocks generally are well-bedded and commonly contain coarser interbeds of material composed almost entirely of slightly rounded volcanic rock fragments up to 3 mm in diameter with calcite, minute angular quartz grains, and opaque volcanic dust or argillaceous material in the interstices.

Tuffaceous rocks also occur in the Mariposa formation, especially in the Angels Camp quadrangle, where they are abundantly exposed. These rocks, which are largely dark-gray to greenish gray tuffaceous sandstone and graywacke, contain a great variety of angular to rounded or platy fragments and small pebbles. Most of the rocks are foliated; the foliation is due chiefly to shearing effects. The mineral and rock fragments, which range in size from 4 mm to 0.01 mm, commonly are separated from one another by nearly black streaks of extremely fine-grained opaque material, probably argillaceous, representing the matrix.

The tuffaceous sandstone and graywacke of the Mariposa formation (fig. 11) contain abundant fresh augite in angular to subhedral pale-green crystal fragments as well as in euhedral to subhedral crystals and phenocrysts in angular porphyritic volcanic rock fragments. Angular fragments of andesitic and basaltic lavas are common. Subangular to rounded grains and small pebbles of vein quartz and quartzite or chert are scattered throughout the rocks; these fragments are considerably less angular than the volcanic rock fragments, which suggests that they were transported greater distances. Other fragments include platy pebbles of slate, phyllite, and quartz-muscovite schist; most of the schist fragments are oriented parallel to the foliation of the graywacke, but a few are oriented nearly at right angles to that foliation, suggesting that they were metamorphosed prior to incorporation in the graywacke. Slightly altered fragments of andesine and labradorite occur sparsely in these rocks, along with plagioclase that has been thoroughly saussuritized. Chlorite, with a deep-blue anomalous interference color, is associated with some of the volcanic rock fragments and may have resulted from the breakdown of pyroxene. A few fragments appear to be composed of granitic materials; in some fragments orthoclase is abundant. In one thin section a rounded grain of calcite was observed, about 1 mm in diameter.

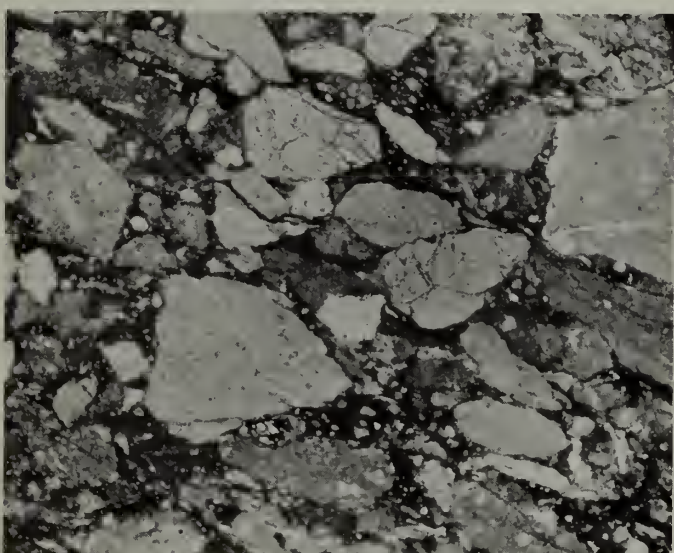

Figure 11. Photomicrograph of graywacke from the Mariposa formation. (X25) The rock is composed of angular to sub-angular grains of volcanic rocks, slate, augite, and altered plagioclase, with some rounded grains of quartz and quartzite.

The tuffaceous sandstone or graywacke of the Mariposa formation represents a mixture of material from two sources—rounded and platy material transported from a metamorphic landmass that was being eroded, and angular mafic volcanic material that was deposited without much transportation.

Mafic Volcanic Rocks

Breccia, agglomerate, and fine-grained tuff are common in parts of the Logtown Ridge formation. Fine-grained tuffs are also characteristic of the Cosumnes formation. These rock types make up the mafic volcanic rocks.

Tuff. Fine- to medium-grained tuffs are common in parts of the Cosumnes formation. They are light-gray thin-bedded rocks with a very poorly developed cleavage. Their chief component is plagioclase in subhedral to anhedral crystals ranging from particles the size of dust up to crystals 0.05 mm long. Many angular fragments of porphyritic, amygdaloidal, and vesicular volcanic rocks averaging about 0.05 mm in diameter are present in the tuffs. A few fresh grains of augite, and scattered laths of green hornblende, partly altered to a colorless negative chlorite, can be seen in thin sections of the rock. Magnetite is common in irregular patches and streaks. Quartz and some calcite are secondary and occur in veinlets or cavities.

Most of the feldspar crystals are clouded with sericite and clinozoisite, or epidote, or both, and have a composition generally between An_5 and An_{10}, but a few of the unaltered feldspar grains have a composition that lies within the andesine field.

Many of these rocks are slightly sheared, and in places the grains are somewhat crushed along edges or sharp corners.

The mafic andesitic or basaltic tuffs of the Logtown Ridge formation also are fine grained, with an average grain size of about 0.05 mm. Fresh angular grains of subcalcic augite (Benson, 1944) are abundant, making up about 40 percent of the rock. Albite clouded with clinozoisite or epidote and sericite makes up another 40 percent, and the rest of the rock consists of brownish to brown-green irregular patches that probably were glass but now are altered to chlorite, bowlingite, and possibly chlorophaeite, and a very fine, nearly opaque dust.

Associated with the tuffs are lapilli tuffs (fig. 12) that contain angular to subangular fragments, up to 3 cm in diameter, of volcanic rocks, some of which are scoriaceous.

Subcalcic augite (having a small optic angle, 35°-40°) and saussuritized plagioclase are common minerals both in the rock fragments and in the enclosing tuffaceous matrix. The augite is colorless to pale green, and the angular to subhedral crystals are unaltered both in the tuffaceous matrix and in the porphyritic fragments of volcanic rock. The composition of both matrix and fragments is andesitic or basaltic.

Breccia and Agglomerate. The coarse volcanic breccia and agglomerate of the Logtown Ridge formation are dark green to gray green and are composed of coarse rounded, subangular, and sharply angular fragments and blocks, ranging in diameter from about an inch to a foot, closely packed together in a fine-grained tuff matrix.

Many of the blocks and fragments of volcanic rock in this breccia member are amygdaloidal, and some specimens are distinctly scoriaceous. These scoriaceous fragments generally are less angular than the more massive blocks, and probably are bombs. However, scattered amygdules are common in many of the larger fragments.

The texture of the component blocks is porphyritic, and originally was hyalopilitic, with phenocrysts averaging about 1 mm in length but ranging up to about 25 mm. Pyroxene phenocrysts have been determined to be subcalcic augite (Benson, 1944), and those phenocrysts of plagioclase that can be identified generally have an anorthite content of An_{10} or slightly less, or approximately albite-oligoclase.

In thin section subcalcic augite phenocrysts are seen to be colorless to pale green and pale greenish brown and generally they are fresh, though here and there partial alteration to chlorite is apparent. Around some of the augite grains minute colorless needles of actinolite have formed.

Most of the plagioclase phenocrysts are clouded with minute crystals of sericite, calcite, epidote, and clinozoisite or zoisite. A few of the large plagioclase phenocrysts have been completely altered to albite, calcite, and sericite.

The groundmass also is composed mainly of albite and subcalcic augite. The subcalcic augite of the groundmass is no more altered than the augite crystals occurring as phenocrysts, but plagioclase laths of the groundmass have been completely altered to albite, calcite, and sericite. Scattered throughout the groundmass are small areas of nearly colorless to light-green negative chlorite, with anomalous interference colors, possibly pseudomorphous after original olivine crystals. Small irregular dusty areas, dark in parallel light but nearly isotropic under crossed nicols, probably represent original glass. They contain scattered grains of magnetite or other iron oxides. Many of these dusty areas are white in reflected light and may be in part leucoxene, especially where closely associated with augite.

A few scattered amygdules contain calcite, albite, quartz, chlorite, clinozoisite or epidote, and possibly prehnite. Some of the amygdules have interiors of calcite and rims of albite.

The present mineralogic composition of the rock suggests that most of the original unaltered material may have been augite andesite or basalt. The considerable quantity of calcite, probably resulting from the alteration of plagioclase, suggests an original high content of lime, and the unaltered feldspar may have been andesine or labradorite. The presence of quartz in some of the blocks suggests derivation of these blocks from dacite. The texture is well preserved, even though mineralogic reconstitution of some of the original minerals has taken place. Except along faults, shearing effects in these rocks generally are minor.

Most of these rocks were mapped by Turner (1894) as "diabase and porphyrite," by Turner and Ransome (1897) as "porphyrite," and by Ransome (1900) as "meta-andesite." Knopf (1929, p. 15) called them "augite basalts" but also used the descriptive term "augite melaphyre." Taliaferro (1943, p. 283) identified the altered agglomerates of the Logtown Ridge formation at the type locality as "augite andesite." Locally many different names are applied to these rocks, including "blue granite." The rocks have been altered sufficiently so that petrographic identification of the present mineral assemblage does not necessarily give an accurate idea of the composition of the original unaltered rock. Inasmuch as these rocks are characterized by the presence of augite, perhaps the best field names are augite melaphyre or augite greenstone.

Mafic and Ultramafic Intrusive Rocks

Masses of gabbro, diorite and serpentine together with diabase dikes comprise the mafic and ultramafic intrusive rocks of the area.

Gabbro and Diorite. Closely associated with the serpentine bodies that lie within the chlorite 1 subzone are mafic intrusive rocks called gabbro in this report. The gabbro is probably approximately contemporaneous with, or a differentiate of, a peridotite magma that now is represented by the serpentine. Actually there is some variation, both textural and mineralogic, in the gabbro. Locally the composition is nearer that of a diorite, and the larger areas of these rocks have been mapped as diorite; in other places, where hornblende is especially abundant, the name hornblendite has been used on the maps. Texturally, the rocks range from fine-grained granular to coarse-grained, somewhat porphyritic types. These variations are gradational.

The gabbro is closely associated with serpentine except in the chlorite 2 subzone in the southeast part of the Sonora quadrangle. The gabbro is massive except along faults and shear zones, and has a fairly well-developed jointing. It weathers readily to a red-brown soil, which supports an abundant growth of vegetation that obscures outcrops.

Textures within the bodies of gabbro range from fine-grained holocrystalline hypautomorphic granular, to very coarse-grained, somewhat porphyritic with phenocrysts up to an inch long in a coarse-grained hypautomorphic granular groundmass. Such large phenocrysts usually are plagioclase, but large crystals of uralitized pyroxene also are common. In general, however, the gabbro is medium grained and massive.

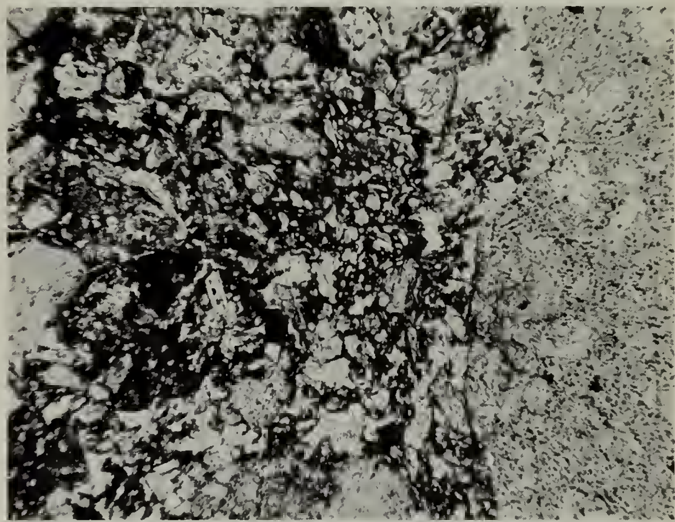

FIGURE 12. Photomicrograph of lapilli tuff of the Logtown Ridge formation (X25) from near Quartz Mountain, Sonora quadrangle. Top of picture shows large fragment of porphyritic volcanic material with phenocrysts of augite and altered plagioclase; dark spots are probable leucoxene which have magnetite or ilmenite grains in their centers. In the center of the photograph is a smaller vesicular porphyritic rock fragment; dark material is interstitial dust.

Under the microscope, an incipient crystalloblastic texture is seen to have been superseded by the growth of low-grade metamorphic minerals.

The mineral composition of the gabbro is as follows:

Mineral	*Approximate percentage*
Plagioclase	15
Green hornblende (uralitic)	20
Augite	10
Actinolite	10
Chlorite (penninite and clinochlore ?)	5
Zoisite	25
Clinozoisite or epidote	10
Pumpellyite (?), Sericite, Calcite, Leucoxene, ilmenite, and magnetite, Pyrite, Apatite	5

Plagioclase occurs as crystals that average about 4 mm in length in the typical medium-grained gabbro, and shows a considerable range of alteration. In some specimens, complete alteration to albite, clinozosite, sericite, and in places calcite has taken place, whereas in other specimens the plagioclase is seen to be only slightly altered. A single thin section may show this variation in degree of alteration of plagioclase; some of the feldspar has been completely saussuritized and other crystals have been changed only slightly. Composition of the slightly altered material is near An_{52}. Unaltered plagioclase, if present, would probably have a still higher anorthite content and would be well within the labradorite field or possibly well into the bytownite field. In some of the rocks, saussuritized plagioclase appears to have been in part replaced by fibrous pale-green actinolite. This mineral occurs in rocks that are near sheared contacts where crushing and shearing effects can be noted.

The common ferromagnesian mineral in the gabbro is pale-green uralitic hornblende, which is pleochroic with X colorless and Z pale green. It probably has replaced pyroxene and in turn has been partly replaced in some of the specimens by chlorite. The green hornblende owes its presence to at least two possible sources. (1) It may be a pseudomorph after earlier brown hornblende that formed as the result of the reaction of augite with paulopost magmatic liquids. According to Hutton,[14] early-formed brown hornblende may be deficient in (OH), and addition of (OH) at a later period may result in the formation of the pale-green variety. (2) The pale-green uralitic hornblende may have formed directly as a replacement of an iron-poor augite. The absence of brown hornblende in these rocks suggests that origin (2) is correct. Moreover, in a few sections the hornblende is seen to contain minute inclusions of augite, all of which extinguish together. In either event the large green crystals of hornblende, so common in the gabbro, are secondary.

Augite is rare in the gabbro; commonly it has been completely replaced pseudomorphically by green uralitic hornblende. In places, however, augite crystals are found to be only partly replaced. Crystals of this sort usually are slightly replaced near their centers and completely altered around their borders, with lamellae of amphibole extending into the center along planes of cleavage and parting. The augite is a colorless and nonpleochroic variety, suggesting a low iron content.

Fine-grained fibrous actinolite has replaced the earlier-formed green uralitic hornblende where crushing and shearing of that mineral has occurred. The actinolite, nearly colorless, is thought to have been formed as a result of low-grade dynamometamorphic stresses upon the gabbro. Locally the actinolite seems partly to have replaced, or to have grown into, plagioclase, a situation that possibly has resulted from recrystallization of anorthite-rich plagioclase and uralitic hornblende to give actinolite, albite, epidote, and aluminous chlorite.

At least two varieties of chlorite are found in the gabbro. The common one, possibly penninite, is pale green to nearly colorless and exhibits strong blue anomalous interference colors and very low birefringence; inasmuch as the elongation is positive, the optic sign is negative. Associated with this chlorite, usually as a selvage, is a pale-green chlorite, with negative elongation; this mineral may be clinochlore or positive penninite. Anamalous colors are almost lacking in this variety. These two chlorites commonly replace hornblende and augite.

Zoisite, clinozoisite, sericite, and possibly pumpellyite occur as products of saussuritization of calcic plagioclase. Generally these minerals are very fine grained and give the plagioclase crystals a dusty appearance in parallel light; between crossed nicols with the feldspar in extinction, a host of bright specks appears against the black background. In a few places zoisite is present in grains up to about 0.5 mm long and is characterized by a deep-blue abnormal interference color. Clinozoisite, in grains up to about 0.2 mm long, has formed in irregular veinlets and patches in some of the rock. Some of these grains have a yellow interference color and may be iron-poor epidote. Tiny needles of pumpellyite are thought to occur in one specimen in which the plagioclase forms large phenocrysts in a medium-grained groundmass of uralitic hornblende and plagioclase.

Calcite, though not a common mineral in the gabbro, is widespread and forms tiny veinlets and narrow elongate patches in the hornblende and plagioclase crystals. It has developed chiefly in rocks that contain chlorite as a replacement in uralitic hornblende and augite, and probably accounts, in part, for the disposition of the calcium ion of the hornblende and plagioclase.

White opaque grains of leucoxene, pseudomorphous after ilmenite and generally exhibiting the skeletal crystals characteristic of that mineral, are widely but sparsely distributed throughout the gabbro. Leucoxene is associated principally with green hornblende, chlorite, and actinolite, and occurs as disseminated grains and minute irregular patches, probably representing titanium contained originally in the altered augite crystals. Rarely, original ilmenite occurs within the central part of a leucoxene grain. Magnetite in these rocks is uncommon, but scattered grains, some with a rim of red iron oxide, can be seen. Pyrite is common, particularly in rocks that show the effects of slight shearing, and in such rocks the sulfide is concentrated in the sheared area. Minute crystals of apatite are found uncommonly in the gabbro of the chlorite 1 subzone.

Fine-grained light-colored dikes that weather to a light brown cut the coarser dark-colored gabbro (fig. 13). These dikes have an average grain size of about 0.5 mm and have a xenomorphic texture. They are composed of plagioclase, somewhat saussuritized and having a composition of An_{52}, together with minor amounts of a pale negative chlorite and a few patches of clinozoisite. Originally these dikes probably were composed chiefly of a calcic plagioclase with a few scattered grains of pyroxene and, if so, were anorthosite.

Serpentine. Serpentine, replacing peridotite, occurs in two large areas and several small ones in the chlorite 1 subzone. Generally this rock is massive, but along faults it has been intensely sheared.

In thin section, between crossed nicols, the massive serpentine is seen to have a pseudoporphyritic appearance with large "phenocrysts," having an interference color of gray of the first order, suspended in a fine-grained matrix of crystals of the same color. In parallel

[14] Hutton, C. O., oral communication.

Figure 13. Altered anorthosite dike in gabbro. The great range in grain size of the gabbro is common.

light, however, the original texture is more clearly seen because of the development of typical mesh structure in which strings of magnetite have outlined the original olivine crystals. The grain size of the larger crystals in these ultramafic rocks is coarse, averaging about 2 to 3 mm, although in some places bastite pseudomorphs may be as long as 5 mm.

The following minerals comprise the serpentine bodies of the mapped area:

Minerals	*Approximate percentage*
Serpentine minerals:	
Chrysotile (both positive and negative (?))	15
Xylotile	2
Serpophite (?)	5
Chlorite minerals:	
Antigorite	10
Chlorite (positive with B near 1.58; low birefringence; possibly clinochlore or prochlorite)	65
Accessory minerals	3
Magnetite	
Chromite	
Picotite	
Carbonate (near ankerite)	

The chief component minerals are believed to have formed in the following sequence: early-formed minerals, serpophite (?), negative chrysotile (?), and antigorite; later-formed minerals, chlorite, antigorite (?), chrysotile, and xylotile.

Dark, nearly isotropic patches of serpophite grade into a mineral of low birefringence that appears to be fibrous and has negative elongation, termed negative chrysotile (?) in this report. The negative chrysotile (?) generally surrounds the dark serpophite centers, and these two minerals probably represent the early replacement of olivine crystals. Antigorite has replaced pseudomorphically large pyroxene crystals to form bastite.

A positive chlorite, clinochore or prochlorite, makes up the bulk of the groundmass of the serpentine rocks. Actually, the mineral described as negative chrysotile (?) may be merely an extremely finely crystalline part of this chlorite, as the boundary between the fibrous-appearing material and the somewhat more platy chlorite is completely gradational. If this is so, then the chlorite is contemporaneous with the serpophite and comprises a large proportion of the rock, probably about 65 percent. That the negative chrysotile (?) actually may be fine chlorite is suggested by one specimen in which dark cores of nearly isotropic serpophite are surrounded by intersecting veinlets and irregular patches of chlorite, and none of the fibrous-appearing material is present. These chlorite veins in places contain a streak of magnetite along their centers, suggesting growth of the chlorite outward from an original fracture in primary olivine. The chlorite crystals are plates slightly less than 0.05 mm in diameter, generally are warped, and have an undulatory extinction.

Antigorite, or an antigorite-like chlorite, occurs in these serpentine rocks as a later-stage replacement mineral. It forms in veinlets, as small individual crystals, or, more commonly, as radiating plumose aggregates of crystals similar to the flamelike serpentine of Du Rietz (1935). It replaces clinochlore (or prochlorite), serpophite, and bastite. The radiating or flame structures are most common where chlorite is seen to be replaced, but similar diverging bladelike aggregates occur in the antigorite of the bastite pseudomorphs. Some of the crystals seem to have formed along the edges of broad bands in the bastite pseudomorphs that may represent original twin planes of the pyroxene. More commonly, this type of antigorite has formed around the edges of the bastite pseudomorphs or along cracks and cleavage planes. In many places the antigorite plates lie at oblique angles to each other, and are best seen where only a few crystals are present. This orientation of the crystals may be along directions of high shearing stress set up within the serpentine bodies during a period of deformation that followed emplacement and alteration to serpentine. Observations of bastite pseudomorphs from these serpentines seem to indicate that the antigorite of the original pseudomorph has, in part, recrystallized to adapt itself to physical conditions different from those under which it formed.

Chrysotile occurs in small veinlets, with the fibers oriented nearly at right angles to the walls of the veins, and cuts across most of the other minerals and structures of the rocks, although in some places the late-stage antigorite appears to be contemporaneous with, or even later than, some of the chrysotile veins. In some of the rocks, small veinlets of xylotile, have strong pleochroism and bright red interference colors, occur with the chrysotile veinlets.

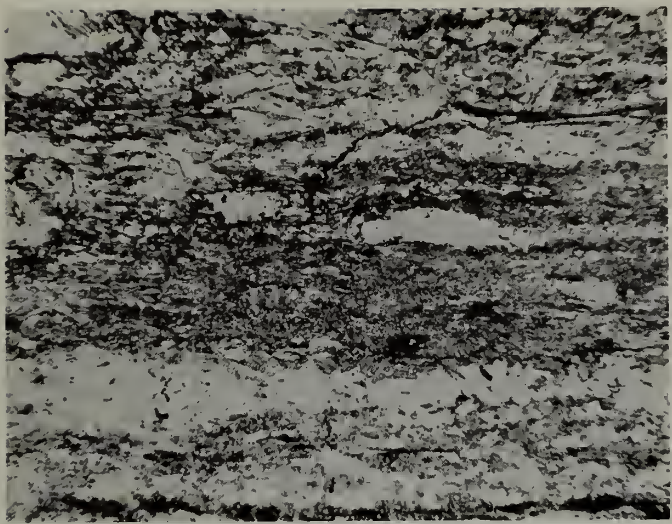

Figure 14. Photomicrograph of phyllonite (X25). Light bands are chiefly quartz with a small amount of albite. Other minerals in darker bands are chlorite, muscovite, actinolite and iron oxides.

Magnetite dust, representing the iron of the original minerals, is abundantly distributed along cracks and parting planes of what were crystals of pyroxene and olivine. Alteration to serpentine and chlorite minerals has expelled the iron, in the form of the oxide, into cracks and fractures, giving rise to the typical and common mesh structure of massive serpentine rocks.

Picotite and chromite are common minerals in the serpentine rocks. The picotite occurs in irregular masses up to several millimeters across and, in parallel light, is deep reddish brown. Chromite, nearly opaque except along thin edges, where a brown color can be seen, occupies irregular patches, and in places is associated with picotite. Chromite occurs chiefly as minute grains, but some crystals are as much as several millimeters across.

Figure 15. Photomicrograph of stretched conglomerate (X25). Section is taken normal to the shear cleavage and intermediate axes, showing long and short axes of stretched pebbles. Rock is composed largely of quartz and muscovite, with minor chlorite, albite and iron oxides. This rock has been considerably sheared and recrystallized and probably could also be called a phyllonite.

Carbonate is rare, but may occur as small disseminated grains or as small veinlets that in places wedge apart the antigorite lamellae of the bastite crystals. The refractive index of most of the observed grains is very close to that of balsam, and the mineral probably is ankerite or an iron-bearing magnesite.

The highly sheared serpentine in the vicinity of major faults is composed almost entirely of a felt of antigorite crystals with patches of talc developed along shear planes.

Porphyritic Diabase. Massive feldspar porphyry occurs as dikes and sills in the rocks of the Mariposa formation and Amador group. The porphyry is dark greenish gray and contains phenocrysts of light-greenish saussuritized plagioclase up to about 15 mm long.

Under the microscope the rock is seen to have an intersertal porphyritic texture with phenocrysts of plagioclase (some slightly saussuritized and with a composition of about An_{40}, but much completely saussuritized) and augite; the latter is less abundant than the feldspar and unaltered. The groundmass is composed of a network of plagioclase laths, abundant small crystals of augite, and minor amounts of brownish-green hornblende. Grains of magnetite, iddingsite, and leucoxene, and a few scattered pools of light-green chlorite, probably pseudomorphous after olivine, are the accessory minerals. Some nearly opaque material, thought to represent original glass, is scattered throughout the rock.

Rocks of the Chlorite 2 Subzone

The rocks of the chlorite 2 subzone have fair to good schistosity; mineral reconstitution is well advanced, and in many places no relicts remain.

The principal rocks of this subzone are:

- Quartzose and argillaceous rocks
  - Phyllite and phyllonite
  - Stretched conglomerate
  - Quartz-muscovite schist
- Quartz-actinolite-albite schist
- Quartz-albite-muscovite-chiastolite schist
- Felsic tuff
  - Amphibole crystal tuff and tuffaceous sandstone
  - Green schist series
    - Albite-actinolite schist
    - Hornblende-andesite
    - Plagioclase-chlorite-zoisite schist
    - Albite-chlorite-epidote schist
  - Marble
  - Mafic intrusive rocks
    - Gabbro
    - Diabase

Quartzose and Argillaceous Rocks

Rock types such as some of the green phyllites, and stretched conglomerate, are relatively easy to distinguish in the field as separate lithological rock units. On the other hand, certain other quartzose and argillaceous rocks are not so easily delineated. Thus, in the northeast corner of the Angels Camp quadrangle the map unit "Pcs" contains the following undifferentiated rock types: phyllite, quartz-muscovite schist, and quartz-mica schist, locally graphitic. In the Sonora quadrangle Pcs includes quartz-actinolite-albite schist in addition to phyllite and quartz-muscovite schist. Quartz-albite-muscovite-chiastolite schist, "spotted schist" is contained in a narrow zone of phyllite near the gabbro intrusive contact of the Sonora quadrangle.

Phyllite and Phyllonite. The phyllite and phyllonite of the chlorite 2 subzone are dark gray to nearly black, and are composed chiefly of quartz, chlorite, muscovite, sericite, actinolite, and dark streaks of iron oxides. Quartzose pebbles and grains have been crushed and recrystallized, and in places streaked out into long augen. Figure 14 shows phyllonite from the mapped area. We think that the chlorite in these rocks has resulted from the alteration of detrital biotite.

Stretched Conglomerate. Conglomerate containing stretched pebbles is exposed in parts of the chlorite 2 subzone. The pebbles consist of a great variety of rocks, including volcanic rocks, slate, phyllite, schist, chert, vein quartz, intrusive rocks (largely diorite), and, in some places, marble that closely resembles the marble assigned to the Calaveras formation. In some of the coarser units of the conglomerate the pebbles attain a length of as much as 18 inches, but lengths of 1 or 2 inches are more common. In places the larger pebbles clearly have been stretched more than the matrix, which consists chiefly of chlorite, sericite, and fine angular quartz grains. In a very general way the amount of stretching increases toward the northeast: that is, in the conglomerate of the chlorite 1 zone pebbles are practically undeformed, whereas in the chlorite 2 zone some of the pebbles have axial ratio of as much as 1:2:8.

Generally the long and intermediate axes of the pebbles lie in the planes of shear cleavage, the short axes normal to the cleavage (Fig. 15).

Quartz-Muscovite Schist. Probably interbedded with the marble body in the northeast part of the Sonora quadrangle is light-gray quartz-muscovite schist with interbeds of nearly pure quartzite that contains only a small percentage of muscovite. A photomicrograph of the quartz-muscovite schist is shown in figure 16. This rock splits into thin layers along muscovite bands and exhibits the bright luster typical of rocks rich in sericite and muscovite. The banding is believed to be bedding in a quartzose and argillaceous rock in which clay layers now are represented chiefly by muscovite.

The quartz-muscovite schist is composed primarily of quartz (about 60 to 70 percent) with a granoblastic texture and a grain size averaging about 0.15 mm. Two varieties of muscovite comprise the bulk of the remainder of the rock. The most abundant variety is faint greenish brown, slightly pleochroic, and is found chiefly in the muscovite bands, although it also is disseminated throughout the quartzose layers. The other variety is a completely colorless muscovite that forms better-developed crystals whose preferred orientation is stronger than that of the pleochroic variety. The colorless muscovite is disseminated throughout the rock. The greenish pleochroic variety may have been derived from original detrital biotite flakes that were altered, possibly in part to chlorite, with the separation of iron as the oxide, and later recrystallized to muscovite. In some of the bands in which the pleochroic variety of muscovite is concentrated, a few areas of greenish, low-birefrigence chlorite is partly replaced by the muscovite. Dusty patches of magnetite grains are associated with these areas, which suggests derivation, in part at least, from detrital biotite. In addition, isotropic grains of a pale garnet also are concentrated along the muscovite layers.

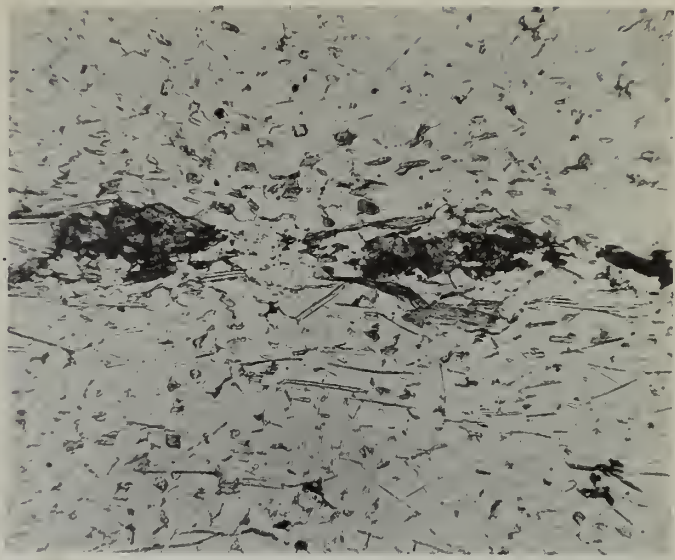

FIGURE 16. Photomicrograph of quartz-muscovite schist (X25). Quartz and muscovite are the principal minerals. Dark patches are areas of magnetite grains and chlorite, probably representing original detrital biotite.

Quartz-Mica Schist. In parts of the area mapped as quartz-muscovite schist, especially in the northeast corner of the Angels Camp quadrangle, brown metamorphic biotite is present. However, the distribution of the quartz-muscovite-biotite schist is so erratic that no attempt has been made to demarcate a quartz-mica schist. The quartz-mica schist (fig. 17) is composed essentially of quartz, brown biotite (altering on its edges to green chlorite), sericite, or fine-grained muscovite, albite, epidote, and minute needles of actinolite. A few of the thin sections show abundant calcite, chlorite, actinolite, and sphene and less tourmaline, leucoxene, and apatite.

Sporadic residual biotite, mostly altered to chlorite, occurs elsewhere in the Angels Camp quadrangle, nota-

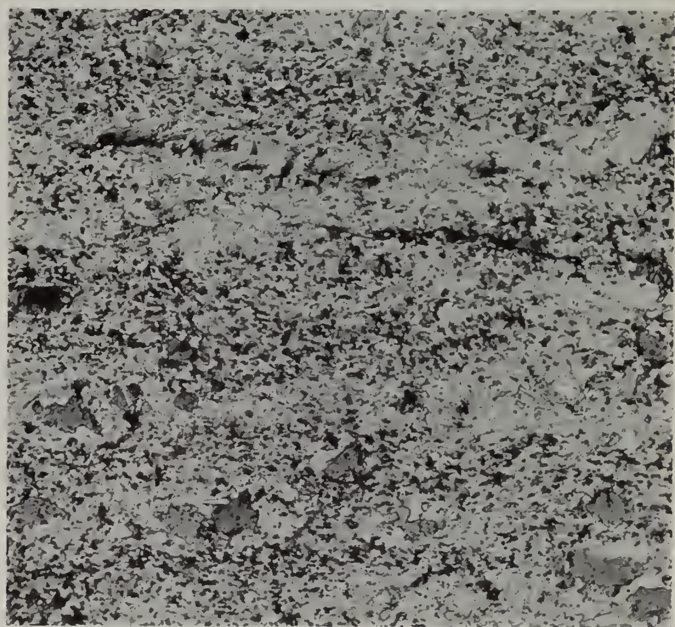

FIGURE 17. Photomicrograph of quartz-mica schist (X25). The irregular dark grains are crystalloblastic brown biotite.

bly in an area about 2 miles southeast of Angels Camp. The presence of this biotite, together with the presence of minute crystals of garnet, suggests that parts of the mapped area have undergone retrograde metamorphism.

Quartz-Actinolite-Albite Schist. Near the east edge of the Sonora quadrangle, the quartz-muscovite schist, described elsewhere in this paper, grades into quartz-actinolite-albite schist. This rock, like the other quartzose rocks in the mapped area, is a fine-grained granoblastic, and has a grain size ranging from about 0.15 to 0.2 mm. The rock has only a crude schistosity and seems to be even less schistose when seen in thin section. Some of the specimens show a faint foliation, which results from barely visible layers of slightly coarser-grained quartz. This foliation may represent bedding.

The quartz-actinolite-albite schist is composed chiefly of quartz (40 percent), actinolite (30 percent), and albite (20 percent); the remainder is muscovite, zoisite, epidote, magnetite, sphene in somewhat opaque patches, and apatite.

The rock is almost entirely crystalloblastic; the quartz and albite occur as xenoblastic grains, among which needles of a colorless to faintly green actinolite has grown. Seattered relicts of a somewhat more deeply colored uralitic hornblende remain in the rock. Muscovite, zoisite, epidote, magnetite, and sphene are disseminated in about equal amounts; apatite is rare, but in a few places it occurs as crystals up to 0.15 mm long.

Quartz-Albite-Muscovite-Chiastolite Schist. Quartz-albite-muscovite-chiastolite schist or "spotted schist" is found in a narrow zone of phyllite and phyllonite in contact with gabbro near the southeast corner of the Sonora quadrangle. This schist is the only rock in the mapped area that shows contact-metamorphic effects.

The spotted schist is composed of quartz, albite, muscovite, chiastolite, iron oxides, and garnet (fig. 18). Quartz and albite form a xenoblastic matrix in which green pleochroic muscovite and streaks of red-brown oxidized iron occur. Porphyroblasts of sericitized chiastolite up to 2 mm long are conspicuous throughout the rock. Garnet in colorless rounded grains is found in minor amounts.

The spotted schist has a fair schistosity; the planes bend around the chiastolite porphyroblasts. Some of these porphyroblasts seem to show slight evidence of rotation and development of coarse muscovite along the edges where shearing stress was greatest. Some specimens of the rock contain no chiastolite now, but display streaked out patches of sericite and muscovite that developed from chiastolite. This suggests for the gabbro in this area that intrusion occurred before, or contemporaneously with, the early stages of metamorphism but that dynamometamorphism continued after the emplacement of the igneous material.

Sericite Schist Derived From Felsic Tuff

A lustrous white sericite schist, stained to ferruginous brown where weathered, is exposed along State Highway 49 between Sonora and Jamestown. This rock is made up of quartz in xenoblastic grains about 0.2 mm in diameter, sericite, muscovite, and opaque minerals, possibly magnetite or pyrite. In thin section the rock is seen to be slightly foliated, for the quartz tends to be segregated into definite bands, with the sericite and muscovite interlayered between them. Probably the rock was originally a felsic tuff.

Near Altaville are a few small bodies of schistose rhyolite tuff; this rock is similar to the sericite schist except that it contains crystals of quartz up to 2 mm across.

Amphibole Crystal Tuff and Tuffaceous Sandstone

A more mafic crystal tuff, tuffaceous sandstone, and an interlayered andesite (?) flow extends southeastward from the city of Sonora to the sericite schist derived from felsic tuff. These rocks are well bedded nearly everywhere. Locally they contain distorted fragments of volcanic rocks.

Figure 18. Photomicrograph of chiastolite schist. X25.

These rocks are composed of actinolite, quartz, plagioclase (albite ?), zoisite, epidote, chlorite, muscovite, green hornblende, magnetite or ilmenite, and sphene, and have a crystalloblastic texture. The grains range in diameter from about 0.02 mm to slightly over 3.0 mm for some of the large actinolite crystals.

Actinolite, displaying faint pleochroic colors with X colorless, Y pale yellow-green, and Z pale blue-green, is the most abundant mineral in these rocks. Generally it forms porphyroblastic crystals averaging about 1 mm in length. Aggregates of chlorite occur in places near the ends of the actinolite crystals. The chlorite is nearly colorless to pale green, is faintly pleochroic, and has a positive sign. Quartz, plagioclase (probably albite but with a composition near oligoclase), epidote, and zoisite make up a granoblastic groundmass with grains averaging about 0.5 mm in diameter but with a great range in extremes of size. Rarely, a green amphibole, probably an original clastic hornblende, is seen. Other minerals are scattered plates of muscovite, magnetite or ilmenite, and a few grains of dusty sphene.

Judging from their present composition, these rocks probably are derived from intermediate or mafic, possibly andesitic, tuffaceous material mixed, in part, with components of sedimentary origin and then recrystallized to form actinolitic rocks. The schistosity is only moderately developed and the well-banded appearance of the rock is believed to be due to bedding. Locally quartz is very rare and actinolite is abundant, and at these places the rock probably is a mafic tuff containing no sedimentary material.

Albite-Actinolite Schist

In the vicinity of Sullivan Creek the rocks of the green schist are represented by a fine-grained crystalloblastic albite-actinolite schist with a grain size average about 0.05 mm (fig. 19). Schistosity is very well developed. The principal minerals are albite in xenoblastic grains, and pale-green fibrous actinolite. Epidote and muscovite are scattered throughout the rock in minor amounts. Much of the epidote occurs as fine-grained dusty patches with scattered grains of sphene (?).

In the Angels Camp quadrangle, rocks of the green schist extend in a broad band northwestward across the area. Under the microscope the schist is seen to be composed dominantly of saussuritized plagioclase and actinolite; it includes varying amounts of epidote, clinozoisite, chlorite, and sericite, which in places cause extreme turbidity of the plagioclase. In general, the greener schist seems to owe its color largely to predominance of clinozoisite. The actinolite usually shows a crude planar orientation and rarely a linear orientation; it also occurs as radiating fibers. The groundmass usually is composed of albite, epidote, clinozoisite, chlorite, sericite, calcite, and actinolite, and generally it has been sheared. The preferred orientation of the chlorite, sericite, and actinolite gives the rock its schistosity. In a few thin sections relict augite is present, but most of the augite has been replaced by actinolite or chlorite or both, and in places the actinolite has been replaced by deep-green to colorless chlorite. Minerals that occur sporadically in the green schist of this area are quartz, orthoclase, brown hornblende, leucoxene, apatite, sphene, deep-brown biotite (highly altered to chlorite), mucovite, and mariposite (green chromiferous mica).

Hornblende Andesite

Closely associated with the schist units of the green schist in the Angels Camp quadrangle is a rock mapped as hornblende andesite. This rock occurs in two areas: one just west of Highway 49 between Carson Hill and Angels Camp and one just south of the northwest corner of the quadrangle. This rock does not have a well-developed schistosity, but it is largely reconstituted mineralogically. It consists of massive flows and flow breccias and is quite different in appearance from the associated rocks of the green schist.

The hornblende-andesite is porphyritic, with small but conspicuous phenocrysts of euhedral green hornblende, up to about 5 mm long, in a light greenish-gray fine-grained reconstituted groundmass. In a few places quartz is an important constituent, and the rock is hornblende dacite, but these small areas have not been mapped separately from the main bodies of andesite.

In thin section the hornblende is seen to range in color from pale brownish green to deep green and probably is an original constituent of the igneous rock, although the prominence of green in the color suggests possible uralitization, with loss of iron. Some of the hornblende crystals show nearly colorless splintery ends (actinolite), and alteration to nearly colorless chlorite is common. Plagioclase is represented by cloudy areas of albite, epidote, clinozoisite, and sericite, but some of the altered feldspar forms areas with sericite centers and clinozoisite rims. Apatite is an abundant accessory mineral and probably is primary, as is the quartz of the dacite.

Plagioclase-Chlorite-Zoisite Schist

The schist in the area between Jamestown and Sonora seems to be characterized largely by a less schistose rock in which part of the original structure and texture are retained. Originally the rock was a coarse pyroclastic, probably a mafic breccia and lapilli tuff. The schistosity is only faily well developed, and scattered lenses are massive and jointed. Mineralogic reconstitution, however, is well advanced, and the rock is plagioclase-chlorite-zoisite schist.

A typical specimen from this area contains albite as well as scattered large crystals of plagioclase with the composition of oligoclase; a positive green chlorite; zoisite; epidote; muscovite; and secondary quartz. Albite, chlorite, zoisite (with minor amounts of epidote), and muscovite form a fine-grained crystalloblastic groundmass in which scattered larger relict crystals of partly saussuritized plagioclase occur. Secondary quartz occurs in the rocks as cavity fillings.

Albite-Chlorite-Epidote Schist

Near the village of Stent the schist is albite-chlorite-epidote schist. The rock has a well-developed schistosity and a crystalloblastic texture; the grain size averages about 0.05 mm. Xenoblastic albite and pale-green negative chlorite make up the bulk of the rock through which small subhedral crystals of epidote are distributed. Some of the epidote crystals are porphyroblastic and have a maximum diameter of about 0.5 mm. In addition to these minerals, the rock contains a few widely scattered grains of calcite and magnetite.

Lenses of Greenstone Within the Green Schist

The lenses of unsheared and nonschistose greenstone within the green schist unit are of considerable interest and importance, as they give a clear idea of the original texture, structure, and mineralogic composition of a part, at least, of the material that now comprises the green schist rock unit.

The rocks shown in figures 20 and 21 are typical of the unsheared volcanics from any of these lenses. The rocks are coarse-grained lapilli tuffs. Subangular to angular rock fragments, up to several inches across, are embedded in a coarse-grained tuff matrix. Mineralogically the composition is as follows:

Subcalcic augite (optic angle 35°-40°)
Actinolite
Epidote or clinozoisite (iron-rich)
Chlorite
Albite
Calcite
Muscovite (pale greenish)
Stilpnomelane

Augite occurs as crystals up to 3 or 4 mm long both in the tuff matrix and in the porphyritic rock fragments. In most places the augite is completely fresh and unaltered. Along sheared areas within the massive rock, however, it is in part replaced by colorless needles of actinolite, as shown by figure 18. The fine-grained parts of both the tuff matrix and the rock fragments are crystalloblastic mixtures of albite, actinolite, chlorite, and scattered grains of epidote. Grains of calcite also are disseminated throughout this fine-grained material, but this mineral is more common in amygdules in the rock fragments. A very pale-green pleochroic muscovite occurs in minor amounts in these rocks. Strongly pleochroic brown stilpnomelane, in radiating or sheaflike structures, occurs associated with chlorite, calcite, and albite, especially in and the near amygdules in the volcanic rock fragments. A photomicrograph of one of these fragments (fig. 19) shows the occurrence of stilpnomelane. Stilpnomelane was not found in any of the more schistose rocks.

Judging from the composition, texture, and structure of the material occurring in these relatively unsheared,

FIGURE 19. Photomicrograph of albite-actinolite schist. X25.

massive lenses within the green schist, it seems likely that this rock was derived from andesitic or basaltic tuffs, lapilli tuffs, volcanic breccias, and possibly flows. In areas where shearing has been intense, fine-grained amphibolitic schist has formed; and where shearing has been less intense, only faintly schistose structures obtain.

The differences in mineral composition of the units of the green schist may not be due to initial differences in chemical composition but may represent different physicochemical environments during metamorphism.

Marble

Only one thin section of marble, from the body in the chlorite 2 subzone 1½ miles southwest of Angels Camp, was studied. This section shows only calcite and a few grains and blebs of quartz. The marble is a medium- to coarse-grained gray to pale blue-gray rock that weathers gray to brownish gray. Reportedly it does not have a uniform composition, owing to impurities in the form of clay minerals and magnesia. For this reason the marble near Sonora has not been used extensively for the manufacture of cement. Locally, however, it is used for the production of lime (Heyl, 1949).

Intrusive Rocks

Gabbro. The gabbro of the chlorite 2 subzone is similar to that of the chlorite 1 subzone in that it exhibits considerable textural variations and slight compositional changes locally. Unlike the gabbro of the lower-grade subzone, it has fairly well-developed planar structures near its periphery. Whether these structures are due primarily to flowage during emplacement or to localized shearing effects, or to a combination of the two, we do not know. Such planar structures might be due to shearing effects during metamorphism, as there is some evidence suggesting intrusion of these rocks during the period of active orogeny and metamorphism.

In general the gabbro of the chlorite 2 subzone is a medium- to coarse-grained rock containing large crystals of green uralitic hornblende up to 4 mm long set in a crystalloblastic groundmass composed principally of zoisite, epidote, and muscovite, with scattered crystals of apatite, sphene, and magnetite. Quartz occurs in minor amounts and, in all sections studied, is secondary. In some specimens, small cores of pyroxene, completely surrounded by the uralitic hornblende, still remain unaltered. Small needles of actinolite have developed around some of the uralitic hornblende, and in some specimens a colorless positive chlorite has replaced the hornblende in part.

In some of these rocks, the zoisite and epidote crystals attain a size of about 0.5 mm and in places make up almost 50 percent of the rock.

In the field, the gabbro appears massive and well-jointed and shows no shearing effects except near its contact with the surrounding sedimentary rocks. Here, where shearing has had more effect, actinolite becomes a more important constituent.

Diabase. Dark-green to nearly black dikes of diabase cut the rocks of the Calaveras formation and are especially apparent where they intersect light-colored marble along Highway 49 north of Sonora.

Phenocrysts of saussuritized plagioclase and uralitized augite, averaging about 4.0 mm in length, are set in a fine-grained granular to diabasic groundmass of altered plagioclase laths, throughout which porphyroblasts of epidote have developed. Scattered muscovite plates and pale-green chlorite are also distributed throughout the groundmass. Accessory minerals are apatite and magnetite. The diabase is somewhat similar in appearance to the porphyritic diabase of the chlorite 1 subzone, but saussuritized plagioclase phenocrysts are smaller and less abundant, and the augite crystals have been completely uralitized.

ECONOMIC GEOLOGY

In dollar value gold has been the most important mineral mined in the mapped area. Plates 4 and 5 list some 500 mines and prospects that are known from published records to exist within the mapped area. Of these, 189 have been identified on the maps by name; this number includes 149 vein gold mines and prospects, 22 gold placer mines, and 18 prospects for products other than gold. Many mine workings have been shown on the maps but their names are unknown to us. Some of these are on unpatented claims, and some may represent the fulfillments of required assessment work.

Except at the surface, the geology of the ore bodies can be interpreted only from published reports; for during the field seasons 1946-48, all of the mines and most of the prospects in the mapped area were inaccessible. Melones adit, in the southwest corner of the Columbia quadrangle, was partly accessible and was mapped (fig. 9).

The vein gold deposits can be divided broadly into (1) those that are associated with faults and fault zones that can be traced for miles, and (2) those that are associated with short, apparently discontinuous faults. Prospects of type (2) have been termed "pocket" mines by local miners. Fault contacts between two rock types have been favorable locales for ore deposition, and volcanic and sedimentary rocks of both chlorite 1 and 2 subzones (see pls. 4 and 5) have been involved. However, most of the gold mines and prospects within the mapped area occur in mineralized schist of the chlorite 2 subzone.

Gravels of Quaternary and Tertiary age have been placered for gold.

In addition to gold and to the silver and copper recovered as byproducts from gold ore, several other products have been mined within the mapped area but to a lesser extent than gold. Limestone and materials for rock aggregates have economic possibilities, for just outside the quadrangles mapped, in the Standard and Columbia quadrangles in Tuolumne County and in the north half of the San Andreas 15-minute quadrangle in Calaveras County, limestone is an important product. In fact, with the economic conditions prevailing in 1950 limestone is probably the most important commodity mined in the Mother Lode region.

Gold

History and Production

The bibliography on the history and romance of gold mining in the Mother Lode is voluminous. James Marshall was not the first man to find gold in California (Jenkins, O. P., 1948, p. 13), but his famous discovery of gold in 1848 at Sutter's Mill in Coloma caused worldwide repercussions that makes the episode a turning point in the history of California. For the news of gold started a tremendous flow of immigrants to California, many of whom never attained their ambitions in mining but nevertheless accelerated the development of California in other fields. The remarkable find at Coloma was soon followed by many other discoveries on the entire length of the Mother Lode belt—both placer and vein deposits.

No attempts have been made to compile production tables for the mines and prospects listed in this report. The reader interested in any particular mine or prospect can obtain the information available by referring to the bibliography in tables 3 through 8. Exact production figures are unobtainable. However, resumés of the productions from Calaveras and Tuolumne Counties are contained in the various California State Division of Mines bulletins and in the publications by Julihn and Horton (1938, 1940), which afford a generalized concept of the magnitudes of production. The files of the U. S. Bureau of Mines, Metal Economics Branch, San Francisco office, is another source of information. More or less systematic figures on production were first available in 1880, the year that the first volume of "Mineral Resources of United States" came out. Prior to 1880 the Mother Lode gold output is anybody's guess.

At first placer mining was more productive than lode mining, as the placers afforded the accessible gold near the surface. Both Tertiary and Quaternary gravels have been placered for gold. The importance of placer gold can be expressed by quoting from Julihn (1938, p. 11).

"In 1909, Lindgren estimated that, of the $1,500,000,000 in gold California had then produced, only about a fifth of it had been derived from lode mines, the balance having included about $300,000,000 obtained from Tertiary and about $900,000,000 from Quaternary gravel deposits. The $500,000,000 of this huge output produced in the first 10 years after the discovery of gold in California must have been derived chiefly from placers in the vicinity of the Mother Lode, which was the early center of California mining activity."

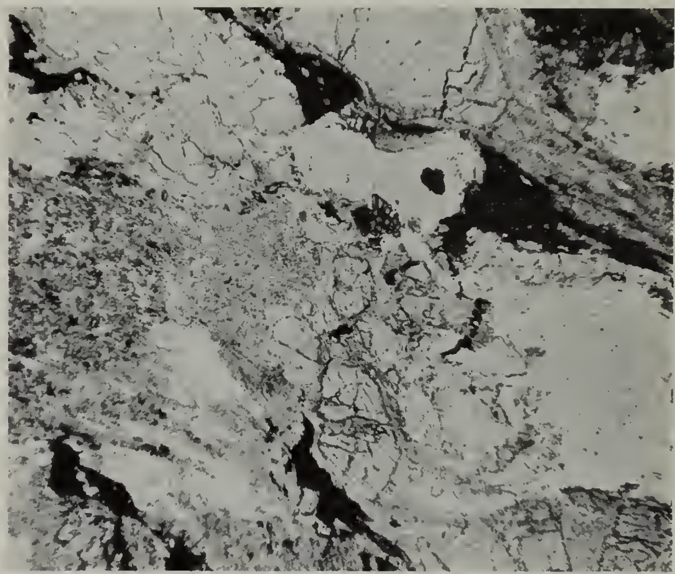

Figure 20. Photomicrograph of relatively unsheared lens of greenstone within the green schist.

These figures show that the total values obtained from placer deposits outrank the gold obtained from vein deposits. These early rich rewards from placer deposits helped finance the search and development of the vein deposits so that the output from the veins increased greatly after the first 30 years of Mother Lode mining.

The early operating methods for placer deposits, hand rocking, sluicing, and hydraulicking have been replaced largely by dredging and dragline dredging methods in recent years. Dredging is especially suited to treating economically the large tonnages of low-grade gravels such as those found in the modern streams. Where Tertiary auriferous river gravels are buried beneath overlying tuffs or flows of lava, drift mining has been successful locally.

All of these operating methods have at various times been employed within the mapped area. For example, the large pit at the San Domingo placer in the north-central part of the Angels Camp quadrangle is reminiscent of the days when hydraulic mining was lawful. And many of the prospects indicated on plates 4 and 5 in Tertiary deposits are silent monuments to drift mining. The tailings indicated on plates 1 and 2 do not give a true picture of the actual amount of gravels treated within the area. In addition to the Tertiary river gravels, gravels of most of the modern streams have been washed and rewashed for gold. In many places Chinese miners gave the gravel tailings a final working over, including those reworked several times by their American predecessors; and through hard work they managed to eke out an existence.

The dragline dredge, which is designed to work in relatively small streams, is today the type most used within the area mapped, where most of the streams are small. The increase in the price of gold in 1934 somewhat stimulated dragline dredging operations. However, the areas available for dragline dredging are limited, and the cost of labor and materials have increased tremendously since 1934, so that in recent years relatively little placering has been done within the Angels Camp and Sonora quadrangles.

As the richest and most accessible of the placer deposits were gradually being depleted, interest grew in the vein deposits. The following mines on vein deposits within the mapped area each have a recorded production of $200,000 or more in gold and have been indicated on plates 4 and 5 with the pick and hammer symbols: Angels, App, Bonanza, Calaveras, Cardinelle, Dutch, Gold Cliff, Golden Gate, Golden Rule, Harvard (Trio), Harvard (Mooney), Heslep, Jumper, Santa Ysabel (Knox & Boyle), Lightner, Morgan, Patterson, Rawhide, Reserve, Sultana, Utica (includes North shaft and Cross shaft). There may be others that should be included in this list. For example, Jackass Hill includes a group of small mines and prospects that have been operated individually and in consolidations under many different ownerships; no one mine has a recorded production of more than $200,000, but the group of prospects on Jackass Hill is famous as a rich producer (Julihn and Horton, 1938, p. 18). Similarly, the Morgan mine, although it was a big producer in itself, can be grouped with the host of mines that later were combined into the Carson Hill Gold Mining Corp.

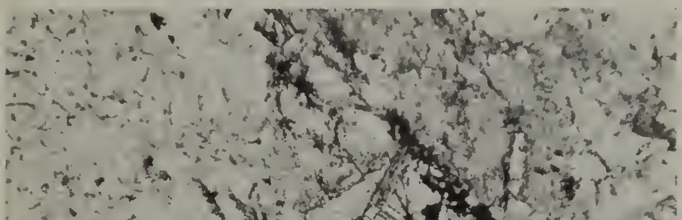

FIGURE 21. Photomicrograph of relatively unsheared pod from within the green schist. Section shown exhibits development of elongate radiating stilpnomelane crystals.

Placer Gold Deposits

For a description of the gravels of the Sierra Nevada of California the reader is referred to the paper by Lindgren (1911).

There are several types of placer gold deposits in the Mother Lode district. Throughout the Cenozoic era the drainage pattern was continually being modified by uplifts, faulting, and intermittent volcanic eruptions (rhyolite flows and tuffs, and andesite flows, tuffs, and mudflows) so that the origin of any one placer deposit may be complex. First, the gold was concentrated by the streams of Tertiary time. Since then, some of the gold deposits have been reconcentrated as the drainage system of the area changed. Finally, the drainage patterns of the Quaternary have had their influence on the placer gold deposits. Some of the modern streams form an angle as great as 90° to the former Tertiary streams in the same locality.

Quaternary Placer Gold Deposits

The sediments of almost every modern stream within the two quadrangles mapped have been washed and rewashed for gold. Many of the streams whose sediments were at first largely washed by hand methods have been re-treated since the development of dragline dredging methods. Dredging operations on the Quaternary gravels within the two quadrangles are becoming less and less rewarding. This is to be expected in areas that are chiefly limited to redredging of old tailings in small streams.

Tertiary Placer Gold Deposits

According to our mapping of the Tertiary within the Angels Camp and Sonora quadrangles there are three principal epochs: the gravelly, the rhyolitic, and the andesitic. The drainage systems during these epochs are complicated further by interrhyolitic and interandesitic periods of erosion. Thus, the gravels of any one deposit may have been reworked several times in the course of its geologic history.

On our maps the gold-bearing gravels are contained in the river gravel of Eocene (?) age or in parts of other gravels that have intersected and reworked the bedrock gravels of the river gravel of Eocene (?) age. Three main Tertiary rivers and their tributaries have affected the gold-bearing gravels within the mapped area, namely, the Tertiary Calaveras River or Central Hill Channel, the Table Mountain Channel or Cataract River, and the Tertiary Tuolumne River. The courses of these Tertiary rivers are shown on figure 1. The Tertiary Tuolumne River may be just south of the Sonora quadrangle rather than within it. Possibly a tributary from it is within the Sonora quadrangle.

Central Hill Channel. The Tertiary Calaveras River, also known as the Central Hill Channel, had its headwaters in the Dardanelles in Tuolumne County, and near Valley Springs it drained into the Tertiary Ione Sea. Its course between these two points is described by Julihn (Julihn and Horton, 1938, pp. 24-27).

Within the Angels Camp quadrangle the course of the former river can be traced from the pattern made by the patches of river gravel of Eocene (?) age Tg as shown on plate 1. Thus the channel enters the quadrangle on the eastern edge in the vicinity of the Vallecito Western mine. From there to the vicinity of the Calaveras Central mine the former river widens into a valley basin in which it developed several channels. The channel then swings northwestward to the vicinity of the San Domingo mine, from where it probably went almost due west. Its continued course, outside the quadrangle mapped, is northwesterly to San Andreas and beyond.

An inspection of the geologic map shows that from the Vallecito Western mine to Calaveras Central to San Domingo to the western edge of the Angels Camp quadrangle the grade of the Central Hill Channel is fairly uniform, about 75 feet to the mile, which approximates a 1.4 percent grade. The pay streaks in the bedrock channels are said (Julihn and Horton, 1938, p. 25) to be 40 to 125 feet wide but in the basin at the Calaveras Central mine they have attained widths of 200 feet. In the San Domingo pit, where the river gravel of Eocene (?) age is well exposed, it is more than 150 feet thick.

Table Mountain Channel. Table Mountain Channel, the northern part of which is also referred to as the Tertiary Cataract Channel, had its headwaters about 12 miles east of Big Trees and an outlet just below Knights Ferry (Lindgren, 1911, p. 215). It entered the Sonora quadrangle a little east of the north-central part of the quadrangle and crossed the area in a southwesterly direction. The channel was filled with a latite flow, probably in late Tertiary time.

Apparently, the gravel beds of the Table Mountain Channel are narrow and thin, as very little river gravel is exposed from under the Mehrten formation (Tm) within the Sonora quadrangle, but parts of the channel have yielded gold. Comparatively rich has been the part between Columbia and Montezuma. Yet, even between these limits only a few of the mines have been profitable. Some of the gold recovered from under Table Mountain may have had as its source auriferous parts of the earlier Tertiary Calaveras River. This is possible, as the Table Mountain Channel probably intersected the Calaveras River Channel near Vallecito, and auriferous gravels could thus have been robbed from the latter channel at this point (see fig. 1). Also, it has been said (Julihn and Horton, 1938, p. 74) that the rich Columbia basin might have been similarly robbed, that is, via a tributary that headed into the Columbia drainage system.

Tertiary Tuolumne River Channel. Figure 1 shows the course of the Tertiary Tuolumne River. It is possible that no part of the main channel is within the Sonora quadrangle as the geologic evidence is too obscure to trace, with exactness, the course of the former river; hence, only a brief mention of it is made here. However, it is possible that the river gravel mapped around Montezuma is in a former tributary that headed northward from the Tertiary Tuolumne River Channel near Chinese Camp.

Undoubtedly, there were other prevolcanic Tertiary streams and tributaries than the ones mentioned, but the evidence is too scattered to permit accurate tracing of their courses.

Vein Gold Deposits

With a few exceptions most of the large producing gold mines of the area follow a definite northwest linear pattern. This linear pattern has been called the main ore zone whereas the large producing mines outside this zone are described as pocket mines. As rich ore has occurred in several different kinds of rocks it follows that structure must have been more important than the composition of the host rock in controlling ore deposition.

The Mother Lode Belt

Figure 1 shows that the Mother Lode belt extends approximately from Georgetown at the north end southeastward to the vicinity of Mariposa, a distance of about 120 miles. The approximate extent of the Mother Lode belt within the map area is outlined on plates 4 and 5. A study of the Mother Lode belt so depicted shows it to be very narrow in the southwest corner of the Sonora quadrangle, to widen to almost a mile at Jamestown, and to continue to broaden northwestward until at the Angels Camp—Altaville area it is more than 2 miles wide.

Broadly, the vein gold deposits can be divided into those that are associated with faults and fault zones that can be traced for miles and those that are scattered, although associated with branching, short, or apparently discontinuous faults. Deposits of the latter type have been termed "pocket mines" by many of the local miners and prospectors.

Main Ore Zone. If one considers only the mines that have a recorded production of more than $200,000 in gold, the Mother Lode belt within the mapped area becomes limited longitudinally, as an inspection of plates 4 and 5 will show. These mines have been indicated on the maps with crossed pick and hammer mine symbols (⚒) to distinguish them from prospects shown with the cross symbols (X). Going from north to south it is seen that of these mines, with large productions in the past, the following are alined along a narrow southeast-trending zone: Sultana, Angels, Lightner, Utica, Gold Cliff, Morgan, Reserve, Calaveras, Rawhide, Harvard, Dutch, App, Heslep, Santa Ysabel (Knox & Boyle), Golden Rule, and Jumper. Such a linear pattern indicates that the Mother Lode belt consists of a major zone of branching and interlacing veins, of which a main ore zone is marked by the mines listed above.

We have no reason to believe that all the good ore deposits are limited to this main ore zone. The fact that there are prospects on branch faults is in itself evidence that ore might exist on faults other than those in the main ore zone. For example, in the Angels Camp quadrangle the fault zone, as roughly outlined by the mines extending from the Yellowstone on the north to the Pure Quill on the south, is an area that is virtually unexplored and has been only superficially prospected.

Pocket Mines. In places, the small mines and prospects that are not on the main ore zone, but close to it, frequently have been termed as pocket mines by many of the local miners and prospectors. Accordingly, a pocket mine seems to be synonymous with a deposit that is small and apparently discontinuous. Some of these pocket mines that are close to, and east of, a major ore zone might be interpreted as leakage fissures or branch veins from the main mineralized fault zone. This could be feasible where the faults, folds, and most of the structures dip to the northeast, thus permitting eastward hanging-wall leakages of the ore solutions that used these structures as conduits.

It is interesting to note that the Jackass Hill group of mines, which are generally referred to as typical pocket mines, and which as a group have produced considerable gold, is situated east of the main ore zone that, to the north and south of Jackass Hill, has contained large producing mines. This might mean either that the Jackass Hill environment was more favorable to ore solutions than the main fault zone to the west of Jackass Hill or that the main fault zone might be rich at depth greater than has yet been explored.

The Bonanza mine is reported (Julihn and Horton, 1938, p. 61) as probably the most famous pocket mine in the United States, and the reader interested in its history is referred to the bibliography listed in table 6. Unfortunately the mine is now inaccessible, and consequently we have been unable to do any underground geologic mapping. However, if the geologic relations at the Bonanza mine are similar to those on Jackass Hill, then the fault zone to the west of the Bonanza mine might be worth investigating. That is, the fault zone outlined approximately by the San Giuseppe—Dickey Boy mines might be a major ore zone to the west of a belt of pocket mines. The Golden Gate mine would then be on a branch from this ore zone.

Structure Versus Composition of Host Rocks as Ore Control. The Mother Lode fault system, rather than the host rocks, probably was the chief controlling factor in ore deposition. Plates 4 and 5 indicate the types of rocks that the various mine workings traverse at the surface. There seems to be no consistency, save that fault contacts between two rock types have been favorable locales for ore deposition. Volcanic rocks and schists of both chlorite 1 and 2 subzones (see pls. 1 and 2), phyllite, marble, serpentine, and gabbro have formed either the hanging wall or the footwall or both of an ore vein.

Knopf (1929, pp. 23-24) has divided the ore bodies of mineralized country rock into two types: mineralized greenstone ("gray ore") and mineralized schist. The difference between the two types is due chiefly to the difference between the rocks into which the mineralizing solutions were introduced. Mineralized greenstone consists of hydrothermally altered massive pyroxenitic volcanics; mineralized schist consists of hydrothermally altered generally schistose amphibolitic volcanics. Mineralized schist has been a favorable host to ore deposition in the mapped area; the least favorable rocks seem to have been those of the chlorite 1 subzone, which are largely slates, and augitic greenstones. The reason that the schists are favorable is almost certainly because of the manner in which they were deformed, rather than their chemical composition, for in nearby areas outside the mapped quadrangles slate and greenstone are the favorable host rocks.

In the southern part of the Sonora quadrangle the main ore zone follows the fault along which rocks of very low metamorphic grade (chlorite 1 subzone) on the footwall side have been brought into juxtaposition with rocks of slightly higher metamorphic grade (chlorite 2 subzone) on the hanging-wall side. But north of the Rawhide mine in the Sonora quadrangle the main ore zone is to the east of this metamorphic boundary and continues east of it through the Angels Camp quadrangle. At least, the large producing mines of the past indicate this course.

Some favorable influence may have been exerted by the mafic and ultramafic intrusive rocks; for example, the intrusives in the areas between Carson Hill and Altaville in the Angels Camp quadrangle and between the Harvard and Alameda mines in the Sonora quadrangle. Shearing along contacts between intrusive and nonintrusive rocks may have opened spaces through which the solutions passed. These rocks, however, do not appear to have been necessary to ore formation, for many of the mines are hundreds of feet from the nearest exposure of intrusive rock.

Thus, structure rather than the composition of the host rock was probably the chief controlling factor of the ore deposits in the quadrangles mapped.

Quartz Veins. The vein deposits are associated with quartz veins and these in turn are localized along faults. Rarely an individual quartz vein can be traced more than a mile along the strike; many can be traced for only a few feet. Although the quartz veins themselves apparently are discontinuous, many of the faults that they occupy can be traced for miles. Because of this fact and the close association of gold with quartz, there has hardly been a quartz outcrop considered too small or discontinuous to merit prospecting. At least, there are "diggings" on almost every showing of quartz in the area mapped.

Thick massive, sometimes complexly composite, quartz veins are abundant but relatively nonauriferous as compared with the wall rocks that contain the chief values. In these wall rocks small anastomosing quartz veins or "stringer leads" are common.

Within the Sonora and Angels Camp quadrangles thick massive quartz veins are conspicuous intermittently from Quartz Mountain northward to the vicinity of the Harvard and Alabama mines just southeast of Table Mountain. Massive quartz veins are prominent again at Carson Hill from where they extend discontinuously northward almost to Altaville. Some of the veins on Carson Hill and Chaparral Hill attain thicknesses of 50 feet locally but thicknesses of 3 to 5 feet are usual.

In the Rawhide and Angels Camp—Altaville areas stringer leads or laminated quartz are common. Generally they consist of 1- to 2-inch interlacing quartz veins within schistose rock that is usually altered. These features have been described in many previous publications, especially in Knopf's work (1929, p. 24) and by McKinstry and Ohle (1949), and will not be discussed further here.

In general the chief values in this region are in the wall rocks of the quartz veins. This is strikingly illustrated on Carson Hill, where the bull veins stand as a great wall separating the hanging-wall and footwall glory holes. Narrow quartz veins and stringers had to be mined, but there is no evidence to suggest that they were any richer than wide veins.

Hydrothermal Alteration

Along the Mother Lode veins, the chief hydrothermal minerals are ankerite, sericite, quartz, chlorite, epidote, pyrite, and mariposite. In the two quadrangles mapped most of the alteration zones are less than 20 feet wide and are not shown on the maps. One prominent zone, locally 400 feet wide, lies between Angels Camp and Carson Hill and is shown on the geologic map as quartz-ankerite-sericite schist. Another similar zone lies west and south of Carson Hill, and is nearly 1,000 feet wide near the southeast corner of the Angels Camp quadrangle. Chlorite schist is associated with some of the veins on Carson Hill, and with the veins of the German Ridge mine. Ankerite-mariposite rock interlaced with quartz veinlets is conspicuous on Carson Hill, Quartz Mountain, and at the Rawhide mine.

East of the Mother Lode fault zone, along some of the faults 2 miles east of Angels Camp, are alteration zones of a peculiar type. These have been mapped as calcite-muscovite-chlorite rock, chlorite-calcite-magnetite schist, muscovite-chlorite-quartz rock, and ankerite-talc schist. So far as is known these types of hydrothermally altered rocks are not associated with gold deposits. In a few places the ankerite-talc schist has been prospected for talc.

The large body of ankerite-talc schist about 3 miles northeast of Angels Camp is presumably derived from the hydrothermal alteration of serpentine, although no serpentine was seen here. A small lens of nonhydrothermally altered gabbro occurs at the edge of the body.

Suggestions for Exploration

Although the gold mines in this area were worked for many years and have lain idle for some time, it is improbable that all the ore has been extracted. In addition to these areas there are many places adjacent to faults where ore bodies may exist. The possibilities for finding large new deposits require more extensive exploration and capital than was necessaary 50 years ago, but unquestionably much gold still remains in the ground.

Unexplored areas also exist in parts of the Central Hill Channel in Tertiary gravels. Yet, intense exploration does not preclude the existence of "missed" ore bodies in veins either to the hanging-wall or to the footwall side of the vein explored.

Most of the mines with large production are alined along a narrow part of the Mother Lode fault system. Along this linear belt three areas have been especially productive: Angels Camp-Altaville, Carson Hill, and the area west and southwest of Jamestown. Some of the areas between the three most productive ones are favorable for more intensive exploration than has been done to date. One is along and near the hydrothermal alteration zone mapped as quartz-ankerite-sericite schist that extends for $1\frac{1}{2}$ miles just west of Highway 49 between Angels Camp and Carson Hill. Another is the part of the Mother Lode fault zone just west of Jackass Hill. Similarly, the ground between the Sweeney and the Harvard mines in the Sonora quadrangle has not been extensively explored. A few small mines and prospects occur along these strips, but so far as can be determined the areas (strips) have never been satisfactorily explored and have been prospected only within a few hundred feet of the surface.

Besides these areas the fault zone $1\frac{1}{2}$ miles west of Angels Camp and the one just west of Sonora merit further exploration. The former is outlined roughly by the mines extending from Yellowstone on the north to the Pure Quill on the south; the latter extends approximately from the San Giuseppe mine to the Dickey Boy mine.

Other Mineral Commodities

Besides gold the following commodities have been recovered from the mapped area: chromite, manganese, copper, talc and soapstone, magnesite, asbestos, limestone or marble, building stone, road metal and riprap, and roofing granules.

Within the Sonora quadrangle chromite probably has been the most valuable nonauriferous commodity mined; and in the Angels Camp quadrangle green schist, used for roofing granules, has been the most valuable nonauriferous product. Neither material has been very extensively mined. Limestone is at present the most actively mined commodity in the Mother Lode district. Most of the marble quarried goes into the manufacture of cement and other lime products.

Chromite, Manganese, and Copper

Tables 5 and 8 indicate that about 25 chromite prospects lie within the mapped area. The chromite prospects are in serpentine. Only two of these prospects are in the Angels Camp quadrangle; the rest are in the west half of the Sonora quadrangle.

All of the operations were small and the workings consist of shallow pits, trenches, open cuts, and a few shafts. According to the tables compiled by Carter (1948, pp. 4, 28-29) most of the production from these prospects was during World War I. Of these probably the Quigg mine only has produced more than 1,000 tons of ore. For more complete descriptions of the geology of the chromite prospects the reader is referred to the California State publication mentioned above.

Manganese has been prospected in two places in the area; both are in the Angels Camp quadrangle. At the Airola prospect, a mile southeast of Angels Camp, the primary ore is chiefly pink rhodonite, which in places extends to within 2 feet of the original surface. Most of the surficial capping of secondary black manganese oxides has been stripped away, and some of this material lies on the dump. Locally, the phyllitic host rock is stained with black manganese oxides.

At the Lavagnino prospect, three-quarters of a mile southwest of Angels Camp, there are several specimens of dark oxide of manganese ore on the dump. The pit is in phyllite.

Copper is recovered as a by-product in some of the gold ore concentrates. The bibliography in table 8 compiled for the copper prospects indicates that copper has been recovered from at least five prospects within the area. However, only very small tonnages of low-grade gold ores yielding 3 to 10 percent copper are reported for the prospects tabulated, and the copper is said to occur as oxides and sulfides with some pyrite.

Talc and Soapstone, Magnesite, and Asbestos

About 2 miles east of Angels Camp, near the Peirano Ranch, a few talc and soapstone deposits have been prospected. The talc is light colored, and some of it appears to be of good quality. The quantity, however, is small; most of the rock near these prospects has been mapped as ankerite-talc schist. Another small talc prospect is near Woods Creek not far west of Sonora.

Small magnesite prospects have been tabulated for the Sonora quadrangle. The veins are in serpentine and are 1 to 2 feet wide. Only from the White Rock magnesite prospect has any shipment been reported: three carloads of magnesite were shipped in 1917.

West and northwest of Rawhide are small asbestos prospects in the serpentine. The fibers are usually under 1 inch, and as yet no commercial asbestos deposits have been developed within the area.

Limestone or Marble, Building Stone, Road Metal, and Riprap

In the Angels Camp quadrangle are a few bodies of marble, but no commercial production has been reported. Because this marble occurs in fault zones, only the larger blocks would be amenable to quarrying operations. No analyses are available, but the mile-long limestone lens $1\frac{1}{2}$ miles southwest of Angels Camp seems to be of good quality.

In the Sonora quadrangle are several lenses of marble along fault zones and some larger limestone bodies within the city of Sonora and northward through Columbia. The southern extension of this body of marble is mined by the U. S. Lime Products Co. (Heyl and Wiese, 1949). Several limestone quarries north of Sonora and Columbia have been active in the past.

For many years the rhyolite tuff beds of the Valley Springs formation have been quarried for building stone. Blocks of this material were used in some of the oldest buildings in the region.

Road metal and riprap are obtained from several dumps in the area, but these materials are not actively quarried at the present time.

At one time volcanic rocks were mined at the Greenstone mine, a former gold prospect southeast of Angels Camp. These rocks were processed into roofing granules (Logan and Franke, 1936, p. 235).

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TABLES OF MINES AND PROSPECTS

in Angels Camp and Sonora quadrangles, California (compiled chiefly from records of the California State Division of Mines and from various Federal publications)

Abbreviations

AR	Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains U. S. Commissioner of Mining Statistics Ann. Rept.
MR	Mineral Resources U. S. Bureau of Mines, Ann. Rept.
CCM	Calaveras County Map, 1896 California State Mining Bureau
RM	Register of Mines and Minerals 1899 California State Mining Bureau
PR	Preliminary Report California State Division of Mines
Roman numerals	Reports of the State Mineralogist California State Division of Mines
B	Bulletin California State Division of Mines
BM	Bulletin U. S. Bureau of Mines
PP	Professional Paper U. S. Geological Survey
IC	Information Circular U. S. Bureau of Mines
M & S	Mining & Scientific Press
Min Ind	The Mineral Industry McGraw-Hill, New York
*	Named on plates 4 and 5

Names in parentheses are alternate names.

Table 3. Gold vein mines and prospects, Angels Camp quadrangle, California.

Name of mine, prospect, or shaft	Location			References
	Sec.	T.	R.	
Adelia*	4, 5	2N.	13E.	XXXII 296
Adeline	33	3N.	13E.	XXXII 296
Albany Flat	10	2N.	13E.	XXXII 296
Alcyone*	17	3N.	13E.	
Allison-Merrimac Group (Merrimac)	14, 15, 23	2N.	13E.	XIII 96, 313
Alta	24	2N.	13E.	RM
Altaville*	28	3N.	13E.	
Altaville (Cherokee)—See Cherokee	29	3N.	13E.	XIII 97; XIV 74
Angels* (Fox, Potter, Valentine Jr.) Claims: Angels, Beda Blood, Billings, Crystal, Doctor Hill, Hennessy, McCormick, Minnie, Oneida	33	3N.	13E.	VI 29; VIII 141; X 150; XII 89; XIII 97, 141; XIV 68; XVII 420; XXXII 297, 322
Angels Camp Deep Mining Co. formerly Brown-Smyth & Ryland Cons. Claims: Demarest, Democrat, Gold Cliff, Hale & Hale Ext., Johnson, Lindsay, Pioneer Suffolk	33	3N.	13E.	XVIII 97, 98; XXXII 239, 297, 299
Angels Deep* (Benson shaft, Pioneer)—See Angels Camp Deep Mining Co.	33	3N.	13E.	XXXII 239
Anna	33	3N.	13E.	XXXII 296; CCM
Ariola	24	2N.	13E.	Field report in files of California State Division of Mines
Bald Hill (Bruner, St. Lawrence)—See Bruner	10	2N.	13E.	
Beda Blood—See Angels	33	3N.	13E.	
Belle	23	2N.	13E.	XII 90; XIII 97; XXXII 297; RM
Belmont Osborn* (Osborn & Bradley, Osborn Prospect, Osborn Cons.)	30	3N.	13E.	XI 172; XXXII 241, 315; B 108, 146; RM
Benson*—See California Gold Mining Co.	30	3N.	13E.	XXXII 247
Benson shaft—See Angels Deep, also Angels Camp Deep Mining Co.	33	3N.	13E.	
Big Bonanza (Oriole, Harris)—See Oriole	3	2N.	13E.	XXXII 298
Big Spring* (Graham) Claims: Graham, Big Spring	3	2N.	13E.	X 150; XI 174; XIV 70; XXXII 298; B 108, 128
Billings—See Angels	33	3N.	13E.	RM; XXXII 298
Birney	26	3N.	13E.	RM; XII 90; XIII 98
Birney & Golden Slipper	29, 30	3N.	13E.	XXXII 298
Black George—See Lindsey	33	3N.	13E.	XXXII 298
Black Oak—See Virginia	19	3N.	13E.	
Blair Cons. (El Dorado, Triple Lode)—See Triple Lode	32	3N.	13E.	XI 172; XII 90, 97, XIII 98; XIV 70
Bolitha* (Hardy)	3	2N.	13E.	XII 93; XIII 99; XIV 22, 71; XXXII 299; B 18, 120, 121
Bovee (Winters, Marshall, Cushing, Sultana)—See Sultana	33	3N.	13E.	XXXII 299; MR '68, 62; RM

Table 3. Gold vein mines and prospects, Angels Camp quadrangle, California—Continued.

Name of mine, prospect, or shaft	Location			References
	Sec.	T.	R.	
Bright Star—See Chaparral Hill	11, 14	2N.	13E.	Field report in files of California State Division of Mines
Brown*	24	2N.	13E.	
Brown (Tulloch) Claims: Eddie B., Little John	11	2N.	13E.	VII 126, 129; X 60; XII 97; XIII 99; XXXII 291
Brown-Smyth & Ryland Cons.—See Angels Camp Deep Mining Co.	33	3N.	13E.	XIV 106; XVII 420, 421; XVIII 97, 98; XXXII 239, 299; B 108; PR 8, 25; RM
Bruner* (Gold Reserve Cons., Bald Hill, St. Lawrence) Claims: Apex, Dewett, Evening Star, Gold Hill, New Discovery, Romaggi & Costa, Spring Gulch Cons. Bruner once owned by Gold Reserve Cons.; 1899 taken over by St. Lawrence Gold Mining Co.	10	2N.	13E.	X 150; XI 174; XII 90; XIII 106; XIV 72; XXVII 297, 299; B 18, 120; B 108 p. 128; RM
Bullion*—See Mother Lode Central Mines, Inc.	10	2N.	13E.	XIV 72; XXXII 300
Calaveras*—See Carson Hill Gold Mining Corp. Claims: Brown, Calaveras, Extension, Iron Rock, Ivanhoe, Mexican, New Year, Relief, Santa Cruz, Stephens	24	2N.	13E.	XI 169, 170; XII 91; XIII 99; XIV 73; XVII 421; XXI 150, 151; XXXII 300; PR 6, 15; B 108, 135, 137
California Gold Mining Co. Claims: Parnell, Benson, Hoffman	30	3N.	13E.	
California Ophir*	14	2N.	13E.	XIV 73; XXXII 300; RM
Canepa*	14	2N.	13E.	XXXII 300
Carabon & Good Chance	22	2N.	13E.	XXXII 300
Carley & Little Carley	29	3N.	13E.	XXXII 300
Carpenter	4	2N.	13E.	MR '68, 71
Carson Creek (San Justo)	23	2N.	13E.	XII 91; XIII 100; XXXII 300, 318; MR '68, 62; RM
Carson Hill Golding Mining Corp. Includes following mines and groups of mines:				PR 8, 15, 27; AR '68, 59, 62; AR 73, 35; Eng. Mng. Jour. (Ward) 1935, 111; PP 157, 71, 176; B 108, 129, 131, 135, 137; BM 413, 9, 12, 20, 101, 109; II 148; IX 37; X 56, 57; XI 169; XII 91, 94; XIII 96, 99, 109, 113, 116, 119; XIV 66, 73, 87, 92, 97; XVII 421, 423; XVIII 98; XIX 16; XX 5; XXI 146, 150; XXVII 435; XXXII 247, 300, 313, 318; IC 6940-April 1917
Morgan	11, 12	2N.	13E.	
Melones	13, 14	2N.	13E.	
Calaveras Mines	24	2N.	13E.	
Chaparral Hill Mines	17, 18	2N.	14E.	
Finnegan group	19, 20	2N.	14E.	
Irvine	13, 14	2N.	13E.	
McMillan	13, 14	2N.	13E.	
South Carolina	13, 24	2N.	13E.	
Champion	17	2N.	13E.	RM
Chaparral Hill Claims: Bright Star, Chaparral Hill, Felicie, Rothschild, Vanderbilt	14	2N.	13E.	XIII 100; XIV 73; XXI 151; B 108, 137
Cherokee* (Altaville)	29	3N.	13E.	XIII 97; XIV 74; XXXII 296, 301; RM; AR '68, 70
Claude*	10	2N.	13E.	XXXII 301, CCM
Clifton Ranch*	29	3N.	13E.	
Cloud	10	2N.	13E.	X 148; XI 174; XIII 100, 101; XXXII 301
Collins & Radcliff	32	3N.	13E.	RM
Columbia*	11	2N.	13E.	XIV 74; XXXII 301; B 108, 137
Confidence	33, 34	3N.	13E.	RM
Cook	23	3N.	13E.	XII 91; XIII 101; XXXII 301; RM
Cosgrove	33	3N.	13E.	XIII 101; XIV 75; XXXII 301
Costa	3	2N.	13E.	
Crosette*	26	3N.	12E.	
Crystal*—See Angels	33	3N.	13E.	XIII 101; X 61; XXXII 302; RM
Curiosity*	5	2N.	13E.	
Curtis*	29	3N.	13E.	
Cushing (Bovee, Marshall, Sultana, Winters)—See Sultana	33	3N.	13E.	XXXII 302
Dead Horse*—See Utica	33	3N.	13E.	XXXII 302; RM; CCM
Demarest*	33	3N.	13E.	
Democrat	33	3N.	13E.	RM; CCM; B 108, pl VI
Doctor Hill—See Angels	33	3N.	13E.	XII 92; XIII 112; XIV 76; XXXII 303; AR '68, 64; B 108, 127; RM
Drake Properties	3, 4	2N.	13E.	B 18, 121; XXXII 303
Dubovonich, Dalmazia & Austrea—See Vonich	21	2N.	13E.	
Duffy	33	3N.	13E.	RM
Eastland—See Lightner	33	3N.	13E.	
Eclipse	29	3N.	13E.	XI 171, XI 92, 97; XIII 102; XXXII 303
El Dorado—See Triple Lode	32	3N.	13E.	XIII 112; RM
Emeline—See Triple Lode	32	3N.	13E.	RM
Empire Lode & Placer	33	3N.	13E.	XXXII 303
Enterprise—See Melones	13	2N.	13E.	
Eresta	3	2N.	13E.	XXXII 304
Etna King* Claims: Ziegler, North End, Widow	33	3N.	13E.	XIV 77, 78; XXXII 304, 323; B 108, 151, 152
Evening Star*	32	3N.	13E.	XXXII 304; RM; CCM
Extension	14	2N.	13E.	RM
Fairfax and Centennial (Waterman)	33	3N.	13E.	XXXII 304
Fazzi—See Jolly Tar & Mariposa	28	3N.	13E.	
Finnegan—See Carson Hill* Gold Mining Corp. Claims: Finnegan, Finnegan Ext., Finnegan Purchase, Tarbot Homesite	13, 14, 24	2N.	13E.	XII 92; XIII 104; XIV 79; XVII 421, 422; PR 8, 26; XX 178; XXI 153; B 108, 139
Finnegan Ext.—See Finnegan	15	3N.	13E.	XXXII 304
Foster*	33	3N.	13E.	XXXII 305; RM
Fox—See Angels	33	3N.	13E.	XXXII 305
French & Wood	20, 29	3N.	13E.	XXXII 305
Fritz—See Sultana	28, 33	3N.	13E.	XIII 104; XXXII 305; RM; CCM
G.A.R.—See Tracy	2	2N.	13E.	XXXII 305
Garibaldi*	24	3N.	12E.	XIV 80; XXXII 305; RM
George Curtis (Star of India)	31, 32	3N.	13E.	XIII 101, 120; XXXII 302; RM
German Ridge & Jupiter*	15, 16	3N.	13E.	X 148; XI 149; XIII 105; XIV 80; XXXII 305; B 413, 133
Ghost* Claims: Tryon, Garnett, Reidel, Harwood, Ladd, Last Chance	33, 34	3N.	13E.	XIII 105; XIV 80, 81; XXXII 305
Gold Cliff* Claims: Pilot Knob, Gold Cliff, Madison, Fairfax, Excelsior, Peachey No. 1, Peachey No. 2	33	3N.	13E.	X 150; XII 92, 93; XIII 105; XIV 81, 82; XVII 422; B 18, 111; B 108, 140, 141; PP 157, 71, 72; RM; M & S Nov. 26, 1904
Gold Hill, Gold Hill Ext.* Claims: Clark Cons., Osborn Placer, Osborn Truax	32	3N.	13E.	X 170; XI 171; XII 93; XIII 105; XXXII 242, 306; RM
Gold Hill*	11	2N.	13E.	XII 9; XIII 105; XXXII 306
Gold Leaf	3	2N.	13E.	XXXII 306
Gold Reserve Cons.—See Bruner	10	2N.	13E.	XIII 106
Gold Valley	32	3N.	13E.	XIII 106; XXXII 307; RM
Golden Cup	?	3N.	13E.	XIII 106; XXXII 306
Golden Star*	2	2N.	13E.	RM
Gould Claims: Boston, A.P.A., Diego, Tariff Reform	14	2N.	13E.	XIV 83; XXXII 307
Graham (Big Spring)—See Big Spring	3	2N.	13E.	
Great Western*	28	3N.	13E.	XXXII 307; B 108, 141; RM
Greenstone—See under roofing granules*	34	3N.	13E.	
Hale—See Angels Camp Deep Mining Co.*	33	3N.	13E.	X 60, 147; XII 93; B 108, pl VI
Hardy* Claims: Hardy and McCreigh, Reed	11	2N.	13E.	B 108, 142
Hardy—See Bolitha	3	2N.	13E.	XI 174; XII 93; XIII 99, 112; XIV 71, 86; XXI 154; XXXII 299, 307; RM; B 18, 120; B 108, 142

Table 3. Gold vein mines and prospects, Angels Camp quadrangle, California—Continued.

Name of mine, prospect, or shaft	Location Sec.	T.	R.	References
Harris—See Oriole	3	2N.	13E.	
Haywood & Carpenter Co.	28, 30 31, 32	3N.	13E.	XXXII 308
Hicks*	10	2N.	13E.	
Hog Pen	33	3N.	13E.	
Hogate*	8	3N.	13E.	
Holy Ghost*	34	3N.	13E.	
Imperial*	14	2N.	13E.	XXXII 309
Iron Rock—See Calaveras*	14	2N.	13E.	XII 94; XIII 109; XIV 87; XXVIII 435; XXXII 309
Irvine—See Carson Hill Gold Mining Corp.	13, 14	2N.	13E.	XXXII 309; B 108, 129
Irwin & McMillan—See Carson Hill Gold Mining Corp.				
Ivanhoe—See Calaveras	14	2N.	13E.	
January	33	3N.	13E.	XXXII 309
John Buck	28	3N.	13E.	XXXII 309
Johnnie & Pat	33	3N.	13E.	XXXII 309
Johnson	9	2N.	13E.	XIII 109
Jolly Tar & Mariposa (Fazzi; Mariposa)	28	3N.	13E.	XX5, 178; XXXII 254, 309; BM 413, 128
Jones*	23	2N.	13E.	XI 173; XII 94; XIII 109; XIV 88; XXXII 267, 309
Kentucky—See Morgan	14	2N.	13E.	XXXII 310; B 108, 129; BM 413, 100; IC 6940
Keystone*	29	3N.	13E.	XXXII 310; RM
Keystone—See Melones	24	2N.	13E.	XIII 110; RM
La France	29	2N.	13E.	RM
Last Chance—See Ghost*	34	3N.	13E.	XI 77; XII 94; XIII 110; XIV 89; XXXII 310; B 18, 122
Last Chance	21	2N.	13E.	RM
Lee	27	3N.	13E.	Field report in files of California State Division of Mines
Lightner (Eastland)*	33	3N.	13E.	XIII 110; XIV89; XVII 422; XXXII 311; B 18, 109; B 108, 143, 191; AR '68, 64; BM 413, 45
Lindsey (Black George)* Claim: San Antonio	33	3N.	13E.	X 151; XI 174; XIII 111; XIV 90, 119; XXXII 311, 312; RM
Little John—See Brown	11	2N.	13E.	XXXII 311
Long Gulch	?	2N.	13E.	XIII 111
Longworth & Nugget and Mabel Fay*	32	3N.	13E.	XXXII 311
Madison—See Gold Cliff* Claim: Tulloch	33	3N.	13E.	X 59, 151; XI 171; XII 95; XIII 111; XXXII 312; B 108, 144; RM
Maloney*	13	3N.	12E.	XIII 112; RM; BM 413, 135
Maltman (perlina)*	28	3N.	13E.	XIII 112; XXXII 312; B 108, 145
Marble Springs—See Mother Lode Central Mines, Inc.*	10	2N.	13E.	
Mariposa—See Jolly Tar & Mariposa	28	3N.	13E.	
Marshall—See Sultana	33	3N.	13E.	
Mary Belle	32	3N.	13E.	XXXII 312
Maxwell	32	3N.	13E.	XIII 112; XXXII 312
McCreight	14	2N.	13E.	RM
McKinley	10	2N.	13E.	XIII 112; XXXII 314
McMillan—See Carson Hill Gold Mining Corp.	13, 14	2N.	13E.	XXXII 309; B 108, 129
Meeker*	14	2N.	13E.	
Melones—See Carson Hill Gold Mining Corp. Claims: Alta, Ariola, Belle, Bowers, Placer, Donald C., Enterprise, Keystone, Last Chance, Melones, Mineral Mountain, Quartz Mine, Quartz Placer, Reserve, Squirrel Gulch, Stanislaus, Stanley, Summit Placer, Y.F.O.L.	24	2N.	13E.	See references for Carson Hill
Merrimac—See Allison-Merrimac group				XXXII 313
Mexican—See Caliveras	14	2N.	13E.	
Meyer & Love	29, 32	3N.	13E.	XXXII 313
M. G.	23	2N.	13E.	RM
Midland Group	30	3N.	13E.	
Mineral Mountain—See Melones	24	2N.	13E.	RM; CCM
Mineral Queen	20	2N.	13E.	
Missouri—See Missouri & Santa Ana*	11	2N.	13E.	
Missouri & Santa Ana (Missouri; Santa Ana)	11	2N.	13E.	XXXII 313
Mohawk*	31	3N.	13E.	XXI 156; XXXII 275, 313; B 108, 145
Morgan—See Carson Hill Gold Mining Corp.* Claims: Kentucky, Morgan, Union	13	2N.	13E.	IX 37; XII 95; XIII 113; XIV 97; SVII 423, 424; XXI 147-150; PR 8, 27; B 108, 129-133. See Carson Hill
Morning Star*	3	2N.	13E.	XXXII 313
Morris	11	2N.	13E.	
Mother Lode Central Mines Inc.* Claims: Bullion, Marble Springs	10	2N.	13E.	XXXII 276, 313; BM 413, 111
Murray Bonanza	14	2N.	13E.	XXXII 314
Naples & Venica	19	3N.	13E.	XXXII 314
Nellie*	3, 10	2N.	13E.	
New Year*	13	2N.	13E.	XIV 39, 98; XXXI 314; CCM
North End—See Etna King	33	3N.	13E.	XXXII 314
North Star	13	2N.	13E.	XXXII 314
North Star* Claims: North Star, New Discovery, Yellow Metal, Albany	33	3N.	13E.	XIV 98; XXXII 314; B 108, 145
Nugget—See Longworth & Nugget and Mabel Fay	32	3N.	13E.	XXXII 311
Ohio*	14	2N.	13E.	
Oneida—See Angels	33	3N.	13E.	XXXII 315; RM
Oriole (Harris, Big Bonanza)*	3	2N.	13E.	XIV 99, 100; XXXII 308, 315; B 18, 121; B 108, 145, 146; AR '73, 36
Osborn & Bradley—See Belmont Osborn	30	3N.	13E.	
Osborn Cons.—See Belmont Osborn	30	3N.	13E.	
Osborn Prospect—See Belmont Osborn	30	3N.	13E.	
Panuga*	30	3N.	13E.	
Parnell—See California Gold Mining Co.*	30	3N.	13E.	XXXII 315
Pearlene	30	3N.	13E.	XXXII 282, 315
Pedit*	3	2N.	13E.	
Peirano	14	2N.	13E.	XIII 115, 119; XXXII 315; RM; CCM
Perlina—See Maltman	28	3N.	13E.	XIII 112; XXXII 315; B 18, 120; B 108, 145
Pine Nut*	19	3N.	13E.	XXXII 316
Pioneer—See Angels Deep, Also Angels Camp Deep Mining Co.	33	3N.	13E.	XXXII 316
Pocket Democrat	33	3N.	13E.	XXXII 316
Port Arthur—See Tollgate*	32	3N.	13E.	XXXII 316
Potter—See Angels	33	3N.	13E.	XXXII 316
Prince—See Tollgate	29	3N.	13E.	
Pure Quill*	4	2N.	13E.	XIII 116, XXXII 316
Purnell	4	2N.	13E.	AR '68, 71
Raspberry—See Utica	33	3N.	13E.	RM
Ratcliffe	4	2N.	13E.	AR '68, 71
Reef Rock	13	3N.	13E.	AR '68, 71
Relief—See Calaveras*	14	2N.	13E.	XXXII 317; B 18, 121; RM
Reserve—See Melones*	13	2N.	13E.	X 58, XIII 116; XXXII 317; AR '68, 35, 60, 71; B 108, 133
Riesler Ranch*	32	3N.	13E.	
Rio Vista	25, 26	2N.	13E.	
Romaggi & Costa*	10, 11	2N.	13E.	XIII 101, 117; XXXII 317; RM
Romaggi Family*	11	2N.	13E.	RM
Rothschild—See Chaparral Hill	11, 14	2N.	13E.	XIV 73, RM
Russell*	3	2N.	13E.	BM 413, 133
Sacramento*	29	3N.	13E.	
Safe Deposit*	30	3N.	13E.	
St. Lawrence—See Bruner	10	2N.	13E.	XXXII 319
San Antonio—See Lindsey	33	3N.	13E.	XXXII 318
San Justo—See Carson Creek	23	2N.	13E.	
Santa Ana—See Missouri & Santa Ana	11	2N.	13E.	XXXII 318
Santa Cruz—See Calaveras*	24	2N.	13E.	XXXII 318
Sarah Q	24	2N.	12E.	XXXII 318

Table 3. Gold vein mines and prospects, Angels Camp quadrangle, California—Continued.

Name of mine, prospect, or shaft	Location Sec.	T.	R.	References
Senora	10	2N.	13E.	XXXII 318
Smith & Crooks Claims: Smith, Crooks	11	2N.	13E.	XIV 106; XXXII 318; RM
Smyth (Suffolk)—See Brown Smyth & Ryland Cons., also Angels Camp Deep Mining Co.	28, 33, 34	3N.	13E.	VIII 126; X 147; XIII 99, 120; XIV 106; XXXII 319
South Carolina—See Carson Hill Gold Mining Corp.	13, 24	2N.	13E.	XII 97; XIII 120; XIV 107; XXXII 300, 319; RM; AR '68, 60; B 108, 134
Spring Gulch Cons.—See Bruner	10, 14	2N.	13E.	XIII 120; XXXII 319
Squirrel Gulch—See Melones	24	2N.	13E.	
Stanislaus—See Melones	24	2N.	13E.	XIII 120; XXXII 319; AR '68, 61
Stanley—See Melones	24	2N.	13E.	Field report in files of California State Division of Mines
Star	3	2N.	13E.	XXXII 319
Star of India—See George Curtis	31, 32	3N.	13E.	XII 97; XIII 120; XXXII 319
Stephens	14, 23	2N.	13E.	RM
Stevens*	24	2N.	13E.	
Stickles—See Utica*	33	3N.	13E.	VI 28; VIII 124; XII 97, 98; XIII 120; XXXII 319; RM; CCM; AR '68, 64; AR '73, 36
Stickles & Bennett	33	3N.	13E.	RM
Storm King*	3	2N.	13E.	RM; XXXII 320
Suffolk (Smythe)—See Angels Camp Deep Mining Co. Claim: Smythe	30	3N.	13E.	VIII 126; X 147; XIII 121; XXXII 320
Sultana (Winters, Marshall, Bovee, Cushing)* Claims: Bovee, Fritz Winters Bros. found it 1852; sold to Wm. Bovee; 1884 worked by Capt. Cushing; 1889 Sultana Mining Co. formed.	33	3N.	13E.	XIV 108; XXXII 320; AR '68, 62; B 108, 147, 148
Thorpe*	11	3N.	12E.	X 63; XIII 121; XIV 109; B 108, 143
Three Brothers	11	2N.	13E.	XXXII 320
Thunderbolt	32	3N.	13E.	B 108 Pl VI
Tollgate Claims: Port Arthur, Marshall, Prince, Beaker	29	3N.	13E.	XI 171; XIII 116; XIV 101; XVII 419; XXI 159; XXXII 316, 321; B 108, 148; 28
Tom	30	3N.	13E.	XXXII 321
Tom Hardy	33, 34	3N.	13E.	XI 174
Tracy (G.A.R.)	2	2N.	13E.	XXXII 321; RM
Triple Lode (El Dorado, Blair Cons.)* Claims: Eldorado Emeline, Jumper These consolidated to form El Dorado. Blair Cons. in 1880's and 1890's. Triple Lode Gold Mines, Inc., formed 1920.	32	3N.	13E.	XI 172; XII 90, 97; XIII 98; XIV 70; XVIII 98; XIX 18; XXI 160; XXXII 298, 321; PR 8 28, 29; B 108, 148, 149; RM; AR '73, 36
Tryon Mining Co.	3	2N.	13E.	XXXII 321
Tulloch (Brown)*	11	2N.	13E.	X 59, 151; XI 171; XII 98; XIII 121; XIV 110; XXI 160; XXXII 291, 321; B 108, 149; B 18, 121
Turner	33	3N.	13E.	XI 173; XII 98
Twin Tree	23	2N.	13E.	XXXII 321
Union—See Morgan*	13, 14	2N.	13E.	XXXII 321; B 108, 129; BM 413, 100; MR '68, 62; AR '71, 35; AR '72, 70, 76
Utica Claims: Brown, Confidence, Dead Horse, Jackson, Little Nugget, Raspberry, Stickles, Utica, Washington Before 1900, Utica and Stickles operated as separate mines	33	3N.	13E.	VI pt. 2, 28, 29; VIII 122, 126; X 150, 151; XI 171; XII 98, 99; XIII 121, 122; XIV 110, 112; XXXII 321, 322; B 18, 111, 119; B 108, 149, 150, 151; BM 413, 136; RM; AR '68, 64
Utica* (Cross shaft)	34	3N.	13E.	
Utica* (North shaft)	33	3N.	13E.	
Utica No. 2	30	3N.	13E.	XXXII 322
Valentine, Jr.—See Angels	33	3N.	13E.	XXXII 322
Vanderbilt*—See Chaparral Hill	14	2N.	13E.	XIII 122; RM
Virginia* (Black Oak)	19	3N.	13E.	XXXII 322
Vista	3	2N.	13E.	XXXII 292
Vonich* (Probably same as Dubovonich, Dalmazia & Andrea) Claims: Dubovonich, Fields homestead, Dalmazia II	21	2N.	13E.	XIV 112; XXXII 322
Wagon Rut*	32	3N.	13E.	XXXII 322
Washington—See Utica	34	3N.	13E.	
Waterman* (Fairfax and Centennial) Claims: Fairfax, Centennial	3	2N.	13E.	XIV 112; XXXII 322; B 108, 151
Western Star	33	3N.	13E.	RM; XXXII 322
	4	2N.	13E.	
White Oak	10	2N.	13E.	XXXII 323
White Oak No. 1	11	2N.	13E.	XIII 123; pl VI in B 108
Whittle*	14	2N.	13E.	XII 99; XIII 123; XIV 113; XXXII 323
Winters—See Sultana	33	3N.	13E.	
Yellowstone*	30	3N.	13E.	XI 173; XII 100; XIII 123; XXXII 323
Y.F.O.L.—See Melones	24	2N.	13E.	Field report in files of California State Division of Mines
Ziegler & North End—See Etna King	33	3N.	13E.	

Table 4. Gold placer mines and prospects, Angels Camp quadrangle, California.

Aetna Cons.—See Calaveras Central	21, 22, 27, 28	3N.	13E.	XXXII 356
Aetna*—Part of Calaveras Central	28	3N.	13E.	XXXII 356
Altaville*	21	3N.	13E.	
Amazon—See Purinton	21	3N.	13E.	XXXII 356
Amazon Star	21	3N.	13E.	XXXII 356
Beda Blood	28	3N.	13E.	XXXII 356
Bully Boy*	8	3N.	13E.	RM; AR '72, 75
Calaveras Central Has mining rights in areas formerly controlled by Aetna, Victor, McElroy, Peirano, Reiner mines, the Johnson Ranch, the Slab Ranch and other mines of Calmo Mining & Milling Co.	21, 22, 23, 26, 27, 28	3N.	13E.	B 135, 235; BM 413, 42; XXXII 329
Calmo* (Mound City Mining Co.)—See Slab Ranch, also see Calaveras Central	27	3N.	13E.	BM 413, 42; B 135, 239
Calmo No. 2*	27	3N.	13E.	
Canepa*	26	3N.	13E.	
Carpenter	31	3N.	13E.	XXXII 357
Crosby	28	3N.	13E.	XXXII 358
Golden Queen	11	2N.	13E.	XXXII 343; BM 413, 59
Hecla—See Rainier	28	3N.	13E.	XXXII 359
Jack Rabbit*—See Purinton	16, 17, 20, 21	3N.	13E.	RM; XX 7; XXXII 360
Johnson—See Calaveras Central	22, 27	3N.	13E.	RM; XXXII 360
Jupiter*—See San Domingo	7, 17	3N.	13E.	XIII 109; B 18, 125; XXXII 360
Kentucky*	23, 26	3N.	13E.	RM; XXXII 360; BM 413, 59
Kinney	27	3N.	13E.	RM; XXXII 360
Lichan	28	3N.	13E.	XXXII 360
Lone Star	21	3N.	13E.	XIII 111; XXXII 360; RM; AR '68, 57
Lundt & Drallmeyer—See Purinton	17	3N.	13E.	RM; XXXII 361
McElroy*	28	3N.	13E.	BM 413, 42
Mike Brown*	28	3N.	13E.	

Table 4. Gold placer mines and prospects, Angels Camp quadrangle, California—Continued.

Name of mine, prospect, or shaft	Location			References
	Sec.	T.	R.	
Mound City Mining Co.—See Calmo	27	3N.	13E.	XXXII 351
Nigger Head	21	3N.	13E.	XXXII 361
North Star*	21, 28	3N.	13E.	XIV 120; XXXII 361
Osborn & Gold Hill	32	3N.	13E.	XXXII 361
Ozark*	23	3N.	13E.	RM; XXXII 361
Paragon	23, 26	3N.	13E.	XIV 120; XXXII 362
Peachy	33	3N.	13E.	CCM; XXXII 362
Pierano—See Calaveras Central				BM 413, 42
Purinton	21	3N.	13E.	XX 7; XXXII 350
Claims: Jack Rabbitt, Bonanza, Amazon, Lundt & Dralmeyer, Golden Treasure				
Rainier (Victor)	29	3N.	13E.	XIV 120
Claims: Hecla, Aetna, Vesuvius, Alta				
Reiner shaft—See Calaveras Central	28	3N.	13E.	
Roosevelt—See Val Ranch	23	3N.	13E.	
San Domingo*	7, 8	3N.	13E.	XXXII 350; BM 413, 60
First worked as hydraulic mine Jupiter) then as drift mine (San Domingo)	17			
Simi	23	3N.	13E.	XXXII 363
Slab Ranch (Calmo)—See Calaveras Central	27	3N.	13E.	XX 178; XXI 161; XXXII 351
Starve Out & Brogilio*	28	3N.	13E.	XXXII 363
Val Ranch* (Roosevelt)	23	3N.	13E.	XIV 121
Vallecito Western*	23, 24, 26	3N.	13E.	XXI 161; XXXII 353; BM 413, 25, 38
Victor (Rainier)—See Calaveras Central	23, 26, 27	3N.	13E.	XIV 120; XIX 18; XVIII 99; XX 7, 178; XXI 161; XXXII 364

Table 5. Mines and prospects for products other than gold, Angels Camp quadrangle, California.

Chromite				
Davis*	23	2N.	12E.	B 134 pt. III, 46-59
Stone*	23, 24	2N.	12E.	B 134 pt. III, 46-59
Feldspar				
Angels*	33	3N.	13E.	B 37, 78; B 91, 153
Manganese				
Airola*	35	3N.	13E.	B 125, 75, 106
Lavagnino*	4	2N.	13E.	B 125, 107
Mariposite				
Reserve*	13	2N.	13E.	B 113, 252
Muscovite				
Utica*	34, 33	3N.	13E.	B 113, 251
Roofing granules				
Greenstone*	34	3N.	13E.	XXXII 235
Soapstone and talc				
Peirano Ranch*	1	2N.	13E.	XXI 171; XXXII 235

Table 6. Gold vein mines and prospects, Sonora quadrangle, California.

Alabama*	9	1N.	14E.	X p. 53, pp. 741-742; XII p. 298; XIII, p. 472; XIV, p. 136; XVIII, p. 99; XIX, pp. 19, 74, 145; XX p. 19; BM 424, pp. 28-30
Alameda*	5	1N.	14E.	X, p. 55; XI, p. 508; XII, p. 299; XIII, p. 473; XIV, p. 136; XX, p. 12; XLV, p. 57
Albion Cons.	2	1S.	14E.	XXIV, p. 22; B 108, p. 174; XLV p. 57
Claims: Hardtack, Bob, Defender, Farrington, Great Eastern				
Alhambra	31	2N.	14E.	XIII, p. 473; XXIV, p. 22
Allen	10	1N.	14E.	XIII, p. 473, XXIV, p. 22
Anderson*	2	1S.	14E.	
Anti-Chinese*	32	2N.	14E.	XIII, p. 473; XXIV, p. 22; B 108, p. 174
App*—See Pacific Coast Gold Mines Corp.	22	1N.	14E.	VIII, pp. 660-661; XII, p. 299; XIII, p. 473; XIV, pp. 136-137; XVII, pp. 482-483; XIX, p. 144; B 18, pp. 130-131; see also Dutch; B 108, pp. 156, 157; B 141, p. 50; BM 424, pp. 36-41; PP 157, p. 78
App & Heslep Mining Co.—See Pacific Coast Gold Mines	22	1N.	14E.	B 108, p. 157
Arbona*	32	2N.	14E.	XIII, p. 473; XIV, p. 137; B 18, p. 129; B 108, p. 158
Atlas (Patterson, Waters)	30	2N.	14E.	X, p. 737; XIII, p. 473; XIV, p. 137; XXIV p. 22; B 108 p. 158-174; BM 424 p. 66
Claims: Atlas, Soldier Gulch, Triangle, Triangle Fraction				
Badger (1)	18	1N.	14E.	XI p. 508; XIII p. 474; XXIV p. 23
Badger (2)	13	1N.	14E.	XXIV p. 23
Beckwith & Saunders	36	2N.	13E.	XIII p. 474; XXIV p. 23
Belcher*	2	1S.	14E.	
Bell*	30, 31	2N.	14E.	XIII p. 474; XIV p. 138; XXIV p. 23; B 108 p. 158
Bella Union		1S.	14E.	BM 424, fig. 5
Belmont	25	2N.	14E.	XIV p. 138; XXIV p. 23
Black Slate*	31	2N.	14E.	
Bluett & McCoddle (Carrington)	30	2N.	14E.	X p. 737
Bonanza*	36	2N.	14E.	VIII p. 652; IX p. 37; X p. 736; XI p. 511; XII p. 299; XIII p. 475; XIV p. 141; XVIII p. 99; XLV p. 60; BM 424 pp. 61-62
Claims: Big Bonanza, Little Bonanza				
Brown Bird	2	1S.	14E.	B 108 p. 175
Buena Vista	29, 31	2N.	14E.	B 108 p. 174
Cardinelle* (Jackson Flat & Parallel)	29	2N.	14E.	XIII p. 475; XXIV pp. 24, 30; B 108, pp. 175-176
Carlin	10, 15	1N.	14E.	XIV p. 141; XXIV p. 24
Claims: Carlin Ranch				
Carrington	25, 29, 30	2N. 2N.	13E. 14E.	X p. 737; XIV p. 142; XVIII p. 99; XIX p. 19, 144; XXIV, pp. 11, 36, 37; B 18, p. 129; B 108, pp. 159-175; PP 157 p. 78
Claims: Chileno, Santissima, Rice & Lyons, Stocker, Wilson & Means, Gillis & Fra, Last Chance A; Pine Tree, Bluett, Carrington, Street Ext, Stenchfield				
Chantreau	7	1N.	14E.	XXIV p. 25; B 108 p. 175

Table 6. Gold vein mines and prospects, Sonora quadrangle, California—Continued.

Name of mine, prospect, or shaft	Location			References
	Sec.	T.	R.	
Chileno*—See Carrington	30	2N.	14E.	XIII pp. 482-483; XIV p 142; XVIII pp. 99-100; XIX pp. 19, 144-145; B 18 p. 129; B 108 p. 159; B 141 p. 54; BM 424 p. 66; PP 157 p. 78
Climax*	2	1S.	14E.	
Cloudman—See Erin-Go-Bragh	27	1N.	14E.	XIII p. 476; XXIV p. 25; B 108, p. 175
Colby (Last Chance I) Claims: Fairview	36	2N.	14E.	X p. 737; XI p. 505; XIII pp. 476-483; XXIV pp. 25, 31
Combination—See O.K.	32	2N.	14E.	XIII p. 476; XXIV p. 25; B 108 p. 175
Coughlin	30	2N.	14E.	X p. 737
Cowen	36	2N.	14E.	XIII p. 477
Crystalline* Claims: Crystalline, Shore, Junietta, Harris & Oliver, Ophir, Winnie	9	1N.	14E.	X p. 742; XIII pp. 477-479; XIV p. 143; XVIII p. 99; XIX pp. 19, 74, 145; XX p. 19; XXIV pp. 9, 26; BM 424, pp. 28-30
Defender*—See Albion Cons.	2	1S.	14E.	
Darrow	5	1N.	14E.	XII p. 301; XIII p. 477; XIV p. 143; XXIV p. 26; B 108, p. 175
Dickey Boy*	7	1N.	14E.	
	12	1N.	15E.	
Donovan—See Vulture	16	1N.	14E.	
Dorsey	36	2N.	14E.	XIII p. 477; XXIV p. 26
Dutch*—See Pacific Coast Gold Mines Corp. Claims: Dutch, Sweeney	22, 23	1N.	14E.	X p. 51; XI p. 509; XII p. 302; XIII p. 477; XIV pp. 145-146; XVII p. 482; B 18 p. 130; B 108 p. 161; B 141 p. 50; PP 157 p. 78
East Lode (Last Lode)	32	2N.	14E.	XIII p. 478; XXIV p. 26
Erin-Go-Bragh & Cloudman*	27	1N.	14E.	XIII p. 478; XX p. 20; XXIV p. 27; XLV p. 64; B 108 p. 175
Eureka	36	2N.	14E.	XII p. 302; XIII p. 478; XIV p. 148; XXIV p. 27
Fairview (Little Bonanza)*—See Bonanza	36	2N.	14E.	
Fischer	31	2N.	14E.	XIII p. 478; XXIV p. 27
Florence	33	2N.	14E.	XII p. 302; XIII p. 478; XIV p. 148; XXIV p. 27
Gagnere*	32	2N.	14E.	BM 424, fig. 5
Gandolfo & Rocca	27	1N.	14E.	XX p. 183; XXIV p. 27
Gerrymander Cons.	1	1N.	14E.	XXIV p. 28
Gillis	30	2N.	14E.	BM 424 pp. 65-66
Gold Leaf—See Mountain View (1)	31, 32	2N.	14E.	
Gold Ridge Mining Co.—See Tarantula (2)	1, 2	1S.	14E.	
Golden Gate* Claims: Golden Gate, Golden Sulphuret, Golden Sulphuret Ext.	1 36	1N. 2N.	14E. 14E.	X p. 738; XI p. 511; XII p. 302; XIII p. 479; XIV p. 149, XXIV p. 28; B 18, p. 134
Golden Nugget	2	1S.	14E.	XXIV p. 28; B 108 p. 175
Golden Rule*—See Jumper	27, 35	1N.	14E.	B 108, p. 167
Grand Turk	29	2N.	14E.	XXIV p. 29, 34; B 108 pp. 176, 177
Gray Eagle*—See Santa Ysabel	27	1N.	14E.	XIII p. 480; XXIV p. 29
Greenstone	28	1N.	14E.	XIV p. 135; XXIV p. 7; XLV p. 53
Gross—See Gross-Street Mining Co.	29, 30	2N.	14E.	XIII p. 480; XXIV p. 29; B 108 p. 176
Gross-Street Mining Co.* Claims: Gross, Shaw & Schollar, Street	29, 30	2N.	14E.	XLV p. 66
Harris	16	1N.	14E.	
Harris & Oliver (Winnie)—See Crystalline	9	1N.	14E.	XIII p. 494; XXIV p. 29, 41; B 108 p. 176
Harvard* Claims: McCann, Mooney, Trio, Whiskey Hill, Sobrante, Pacific, Vulture	16	1N.	14E.	X p. 53; XIII pp. 485, 493; XIV pp. 149-151, 164; XXIV pp. 9, 18, 29, 39, 40; XLV p. 60; B 18 p. 130; B 108 pp. 165, 176, 179; BM 424 pp. 30-36
Heslep*—See Pacific Coast Gold Mines Corp.	22	1N.	14E.	VIII p. 660; XII p. 299; XIII p. 473; XIV p. 136; XIX p. p. 144; XX p. 20; XXIV p. 29; B 108 p. 157, 166, 176; B 141 p. 50

Name of mine, prospect, or shaft	Location			References
	Sec.	T.	R.	
Hess*	24	1N.	14E.	
Hitchcock* (Senator Mining Co.)—See Pacific Coast Gold Mines Corp.	22	1N.	14E.	
Imperial	23	2N.	13E.	XXXII p. 309
Independence (4)	29	2N.	14E.	XIII p. 482
Isabella & Gem	5	1N.	14E.	XII p. 303; XIII p. 482; XXIV p. 30; B 108 p. 176
Jackson Flat & Parallel—See Cardinelle	29	2N.	14E.	
John Moore	30	2N.	14E.	X p. 737
John Ore	30	2N.	14E.	X p. 737
Jones	25	2N.	13E.	XI pp. 173-174; XIII p. 109; XIV p. 88
Jumper* Claims: Jumper, New Era, Golden Rule, Bagan Ranch	26, 27, 35	1N.	14E.	X p. 50; XIII pp. 479, 482; XIV p. 152; XXIV pp. 9, 28, 30; XLV p. 69; B 108 pp. 167, 175, 176; B 141 p. 50; BM 424 pp. 41-43; AR '68 p. 42; AR '71 p. 33; AR '72 p. 62
Kaiser	25	2N.	14E.	XIII p. 482; XXIV p. 31
King Solomon	32	2N.	14E.	XIII p. 483; XXIV p. 31
Knox & Boyle—See Santa Ysabel	27	1N.	14E.	X p. 51; XII p. 303; XIII p. 483; B 108 p. 176
Last Chance I—See Colby	36	2N.	14E.	
Last Chance II—See Carrington	30	2N.	14E.	XVIII p. 99; XXIV p. 31
Last Chance III	13	1N.	14E.	XIII p. 483; XXIV p. 31
Last Lode—See East Lode	32	2N.	14E.	
Lead & Tam O'Shanter Claims: Toledo Cons., Buena Vista	31, 32	2N.	14E.	X p. 56; XIII p. 484; XIV p. 154; XXIV p. 31; B 108 p. 177
Little Bonanza—See Bonanza	36	2N.	14E.	
Little Gem (Harris)	16	1N.	14E.	VIII p. 663; X p. 742; XI p. 506; XII p. 302; XIII p. 484; XXIV pp. 27, 31; B 108 p. 177; XLV p. 69
Lone Star—See Tarantula (2)	2	1S.	14E.	XXIV p. 31
Lookout—See Pena Blanco	6	1N.	14E.	XIII p. 484; XXIV p. 32; B 108 p. 177
Lucky Star—See Pena Blanco	6	1N.	14E.	XIII p. 484; XXIV p. 32
McCann—See Harvard	16	1N.	14E.	B 108 p. 177
Madrid	29	2N.	14E.	VIII p. 658
Malone*	34	1N.	14E.	
Mangante	10, 15	1N.	14E.	XIV p. 155; XXIV p. 32; PR 8 p. 40
Manzanita	1, 2	1N.	14E.	XI p. 506; XXIV p. 32
Mark Twain Mining Co. Incorporates the claims of Nevada Wonder Mining Co.	30	2N.	14E.	B 108 p. 159; PP 157 p. 78
Maryatt*	32	2N.	14E.	XIII p. 485; XXIV p. 32; B 108 p. 177
Maryatt North Ext.	29, 32	2N.	14E.	XXIV p. 32; B 108 p. 177
Mascot (2)	10	1N.	14E.	XIII p. 485; XIV p. 155; XXIV p. 32
May & Hunter	36	2N.	14E.	XIII p. 485
Mazeppa*	35	1N.	14E.	XI pp. 509-510; XIII p. 485; XIV p. 156; B 108 p. 177; BM 424 p. 43
Miller & Holmes*—See Santa Ysabel	27	1N.	14E.	XII pp. 302-304; XIII p. 486; XXIV pp. 29, 33; B 108 p. 176; Sonora folio, Econ. sheet
Mooney*—See Harvard	16	1N.	14E.	
Mother Lode	32	2N.	14E.	XIII p. 486; XXIV p. 33
Mountain View (1) (Gold Leaf)	31, 32	2N.	14E.	XXIV p. 33; B 108 p. 177
Mountain View (2)	3	1S.	14E.	B 108 p. 177
Nevada Wonder Mining Co. Claims: Chileno, Carrington Rice, Santissima, Stocker, J. A., J. A. Gillis, Wilson & Means, Pine Tree, Last Chance	30	2N.	14E.	B 108 p. 159; PP 157, p. 78
New Era—See Jumper	26	1N.	14E.	XI p. 509; XIII p. 487
New G. T. Mine—See New Grand Turk	29	2N.	14E.	
New Grand Turk (New G. T. Mine)	29	2N.	14E.	B 108 p. 177
Neubaumer	29	2N.	14E.	XIII p. 478; XXIV p. 34
Nugget*	35	1N.	14E.	XLV pl. 8
Nut Pine	32	2N.	14E.	XXIV p. 34; B 108 p. 177

Table 6. Gold vein mines and prospects, Sonora quadrangle, California—Continued.

Name of mine, prospect, or shaft	Location			References
	Sec.	T.	R.	
Nyman Cons.*—See Santa Ysabel Cons.	22	1N.	14E.	
O.K.*	32	2N.	14E.	XI p. 508; XII p. 305; XIII p. 487; XIV p. 158; XXIV p. 34; B 108 p. 177
Claims: O.K., Combination, O.K. N. Ext.	5	1N.	14E.	
O'Donnell	15	1N.	14E.	XIV p. 157; XXIV p. 34; B 108 p. 177
Olsen	32	2N.	14E.	XXIV p. 35
Omega (Red Cross)*	9	1N.	14E.	XIV p. 158; XIX pp. 19, 145; XX p. 21; XXIV p. 35; B 108 p. 178; B 141 p. 50
Claims: Omega Table Mt. Gravel, Omega, General Hooker				
Ophir (1)	9	1N.	14E.	XXIV p. 35
Pacific	15	1N.	14E.	XIII p. 487; XXIV p. 35; B 108 p. 178
Pacific Coast Gold Mines Corp.	22	1N.	14E.	XVII pp. 482-83; B 108 p. 157; PP 157 p. 78
Took under option: App, Dutch, Sweeney, Hitchcock and Heslep mines				
Patterson*	29	2N.	14E.	VIII pp. 656-657; XII p. 305; XIII p. 488; XIV p. 158; XVII p. 485; XVIII pp. 100-101; XIX p. 74; PR 8 p. 41; XXIV pp. 9, 35; B 108 pp. 170-178
Claims: Patterson, Lennon, Atlas				
Pena Blanco	6	1N.	14E.	XIII p. 488; XIV p. 159; XXIV p. 35; B 108 p. 178
Claims: Pena Blanco, Doctor, Lookout, Lucky Star, Sarah Francis				
Pine Ridge	16	1N.	14E.	XIII p. 488; XXIV p. 35
Pine Tree—See Carrington	30	2N.	14E.	XVIII p. 99
Point Rock	13, 24	2N.	13E.	XIII p. 116
Pride of Tuolumne	31	2N.	14E.	XIII p. 489; XXIV p. 36
Prospect*	3, 6	2N. 1N.	14E. 14E.	XXIV p. 36; B 108 p. 178
Punter	12	1N.	14E.	XIV p. 36
Rappahannock*	5	1N.	14E.	XII p. 306; XIII p. 489; XIV p. 159, XXIV p. 36; B 108 pp. 171, 178
Rawhide*	4, 5, 8, 9	1N.	14E.	X p. 54; XI pp. 507-508; XII p. 306; XIII p. 489; XIV pp. 159-160; XVIII p. 101; PR 8 p. 41; B 18 pp. 129-130; B 141 p. 50; BM 424 pp. 21-28
Rawhide No. 2	9	1N.	14E.	XII p. 306; XIII p. 489; XIV p. 160; BM 424 pp. 21-27
Red Cross—See Omega	9	1N.	14E.	
Reitz Group—See Tarantula (2)	2	1S.	14E.	
Relief & Surplus	29, 30, 32	2N.	14E.	XIII p. 489; XIV p. 160; XXIV p. 37; B 108 p. 178
Rice & Lyons—See Carrington	30	2N.	14E.	X p. 737
Ritchie	32	2N.	14E.	XIII p. 489; XXIV p. 37
Ross	31	2N.	14E.	XIII 490; XXIV p. 37
San Giuseppe*	35, 36	2N.	14E.	VIII p. 654; X p. 740; XII p. 306; XIII p. 490; XIV p. 161; XXIV p. 37
Santa Ysabel Cons.*	22, 27	1N.	14E.	X p. 51; XIII p. 490; XIV p 161; XVIII p. 101; XXI pp. 34, 37; B 18 p. 131 BM 424 p. 41; B 108 p. 17
Claims: Nyman, Knox & Boyle, Miller & Holmes, Gray Eagle, Bastian Ranch Rights				
Santissima—See Carrington Mine	30	2N.	14E.	
Sarah Francis—See Pena Blanco	6	1N.	14E.	XIII p. 490; XXIV p. 37 B 108 p. 179
Senator Mining Co.—See Hitchcock	22	1N.	14E.	
Shaw & Schollar—See Street, also see Gross-Street Mining Co.	29	2N.	14E.	
Shell Ranch	17	1N.	14E.	B 23 p. 201; B 50 p. 248
Shore*	10	1N.	14E.	BM 424 pp. 67-68
Sobrante—See Harvard	16	1N.	14E.	
Sonora Wonder	36	1N.	14E.	XIX p. 145; XXIV p. 38
Stenchfield—See Carrington	30	2N.	14E.	XIII pp. 482, 492; XXIV 39; B 108 p. 129
Street (Shaw & Schollar)—See Gross-Street	29	2N.	14E.	XIII p. 492; XIV p. 163 XXIV pp. 38, 39; B 10 p. 179
Claims: Eleanor				
Sweeney*—See Dutch	15, 22	1N.	14E.	XIII p. 492; XXIV p. 3 B 108 p. 179; B 141 p. 5 pp. 157 p. 78
Swerer	32	2N.	14E.	XIII p. 493; XXIV p. 39
Tam O'Shanter (Lead & Tam O'Shanter)	31, 32	2N.	14E.	X p. 56; XIII p. 484; XIV 154; B 108 pp. 177, 179
Tanzy	36	2N.	14E.	XIII p. 493; XIV p. 16 XXIV p. 39
Claims: Tanzy				
Tarantula*	5	1N.	14E.	XIII p. 493; XIV p. 16 XXIV p. 39; B 108, p. 17
Claims: Tarantula, Tarantula West Ext.	32	2N.	14E.	
Tarantula (2) (Reitz Group: Jones-Tarantula)	2	1S.	14E.	XIV p. 164; XVII p. 48 XXIV pp. 30, 39; B 1 pp. 176, 179
Claims: Tarantula, Lone Star, Omega, Western Ext., Golden Horse Shoe, Boulder Deep, Tarantula Hawk, Gold Ridge.				
Tarantula Hawk—See Tarantula (2)	2	1S.	14E.	
Toledo*	31	2N.	14E.	
Trio mine*	16	1N.	14E.	X p. 53; XIII p. 493; XI pp. 149, 164; XXIV p 9, 18, 29, 39, 40; B 108 p 165, 176, 179; B 18 p. 1
Utopia	31	2N.	14E.	XIII p. 493; XXIV p. 40
Vandelier*	25, 36	2N.	14E.	
Vulture (Donovan)	15, 16	1N.	14E.	XIII p. 493; XXIV pp. 2 35; B 108 p. 179
Waters—See Atlas	30	2N.	14E.	
Whiskey Hill mine—See Harvard	16	1N.	14E.	B 108 p. 165
Wickham*	32	2N.	14E.	XXIV p. 41; B 108 p. 179
Wilson & Means—See Carrington	30	2N.	14E.	
Winnie—See Crystalline	9	1N.	14E.	XIII pp. 477-479
Worcester (1)	32	2N.	14E.	XIII p. 494

Table 7. Gold placer mines and prospects, Sonora quadrangle, California.

Name of mine, prospect, or shaft	Sec.	T.	R.	References
App		1N.	14E.	BM 424, fig. 5
Bedrock Blue Gravel (Virginia)	27	2N.	14E.	XXIV p. 44
Claims: Saratoga, Gold Hunter, Jefferson				
Best Twenty	17	1N.	14E.	XXIV p. 44
Boston	27	2N.	14E.	X p. 738; XXIV p. 44
Buckeye (Rosedale Gravel)	27, 34	2N.	14E.	X p. 737; XIV p. 166; XXIV pp. 44, 46
Claims: Buckeye placer				
Habacker*	20	1N.	14E.	
Hoseg: Dick & Kent	32	1N.	14E.	XXIV p. 45
Humbug Gravel*—See New York	4 33	1N. 2N.	14E. 14E.	X p. 738; XIV p. 167; XXIV p. 45
Jamestown & Comet—See New York	4	1N.	14E.	IX p. 222; XXIV p. 45
Claim: Comet placer				
McKinley	17	1N.	14E.	XXIV p. 45
Montezume Tunnel	20	1N.	14E.	XXIV p. 45
New York*	4 33	1N. 2N.	14E. 14E.	X p. 738; XXIV p. 34; B 141 p. 50
Claims: Humbug, Helen A, Jamestown & Comet, Rawhide				
Punchbowl*	20	1N.	14E.	XIV p. 167; XXIV p. XLV p. 74; BM 424 p.
Claim: Punchbowl Placer				
Rawhide	4, 5 8, 9	1N.	14E.	X p. 54; XI pp. 507-508; X p. 306; XIII p. 489; X pp. 159-160; XVIII p. 1 XXIV pp. 8, 36; PR 8 41; B 18 pp. 129-130; 108 pp. 171, 178
Claims: Rawhide, Raw hide Ranch Placer, Rawhide No. 2, Keggan, Nevells Placer, Martin Placer, Ballard Placer				
Rawhide No. 2—See Rawhide	9	1N.	14E.	XII p. 306; XIII p. 4 XIV p. 160
Rawhide Ranch—See Rawhide	4, 9	1N.	14E.	
Red Hill	29	1N.	14E.	XXIV p. 45
Rimn Cam		1N.	14E.	BM 424 pp. 80-81
Rosedale Gravel—See Buckeye	27, 34	2N.	14E.	
Rough & Ready	30, 31 25, 26	1N. 1N.	14E. 13E.	XXIV p. 46
Table Mt. & Alpha	9	1N.	14E.	XXIV p. 46
Ventura Grubstake	19, 20 29	1N.	14E.	XXIV p. 46
Virginia—See Bedrock Blue Gravel	27	2N.	14E.	

Table 8. Prospects for products other than gold, Sonora quadrangle, California.

Name of mine, prospect, or shaft	Location			References
	Sec.	T.	R.	
Asbestos				
awhide Asbestos Claims No. 1, 2, and 3	5	1N.	14E.	XLV p. 49
Beryl				
amestown	10	1N.	14E.	XXVII p. 90
Chromite				
nnex—See Rough & Ready, Richards	25	1N.	13E.	B 134 pt. III, p. 27
eckwith Ranch Mines Claims: Booker lease, Rosa A, Mapes-O'Hara, Fagen	1	1S.	13E.	B 134 pt. III, p. 20, 28
ooker lease—See Beckwith Ranch Mines				
ggling and Williams	4, 5, 8, 9	1S.	14E.	B 134, pt. III p. 18, 28
agen lease—See Beckwith Ranch Mines	1	1S.	13E.	B 134, pt. III pp. 20, 28
rassely Claims Claims: Horseshoe, Morning Glory, May Faction, Last Chance	25	1N.	13E.	B 134 pt. III p. 26
orseshoe (Pedro Claim)—See Grasseley claims	25	1N.	13E.	
ahl, (Quigg)	6	1N.	14E.	XXIV p. 6; B 76, pp. 213, 225; B 134 pt. III pp. 12-13; Min Ind 1918 p. 84; BM 424 p. 87
ast Chance—See Grassely Claims	25	1N.	13E.	B 134 pt. III pp. 26, 29
opez Lease—See May Faction	25	1N.	13E.	
ackey (Maki, Peter)*	21	1N.	14E.	XXIV p. 6; B 76, pp. 213, 225; B 134 pt. III p. 14; Min Ind 1915 p. 84, 1916 p. 102; BM 424 p. 87
aki, Peter (Mackey)—See Mackey	21	1N.	14E.	
apes-O'Hara—See Beckwith Ranch Mines*	1	1S.	13E.	B 134, pt. III pp. 20, 29
ay Faction (Lopez lease)—See Grassely claims	25	1N.	13E.	B 134 pt. III pp. 26, 29
orning Glory—See Grassely Claims	25	1N.	13E.	
edro lease (Horseshoe)—See Grasseley claims	25	1N.	13E.	
erconi Ranch*	5	1S.	14E.	B 134 pt. III pp. 19-20, 29
ereira (Shafer lease)	25	1N.	13E.	XXIV p. 6; B 76 pp. 214, 225; B 134 pt. III pp. 26, 29; BM 424 p. 87
hoenix	24	1N.	13E.	B 134 pt. III pp. 29, 30
uigg (Kahl)*	6	1N.	14E.	
ichards—See Rough & Ready*	25	1N.	13E.	B 134 pt. III pp. 27, 29
osa A.—See Beckwith Ranch Mines	1	1S.	13E.	B 134 pt. III pp. 20, 29
Rough & Ready (Annex, Richards)*	25	1N.	13E.	XXIV p. 6; B 76, pp. 214, 225; B 134 pt. III p. 27; BM 424, p. 87
Rowe and Swerer	5	1N.	14E.	B 134 pt. III p. 13
Shafer Lease (Pereira Mine)	36	1N.	13E.	B 134 pt. III p. 26
Sims*	5	1S.	14E.	XXIV p. 6; B 76, pp. 214, 225; B 134 pt. III pp. 20, 29; Min Ind 1916, p. 102; BM 424 p. 87
Sullivan and Kahl*	25	1N.	13E.	B 134 pt. III pp. 29, 30
Sunday	5	1N.	14E.	B 134 pt. III p. 13
Copper				
Greenstone—See Mann Copper Mine	28	1N.	14E.	
Kahl Ranch	6, 7	1N.	14E.	XXIV p. 7; B 23 p. 201; B 50, p. 248
Mann Copper Mine Claims: Red Mt. Iron Mine, Greenstone Copper Mine, Copper King Copper Mine	27, 28	1N.	14E.	XIV p. 135; XXIV p. 7; XLV p. 53
Mackey (Ohio Diggins)*	21, 28	1N.	14E.	XLV p. 53
Marianno Iron & Copper Mines	4, 5, 8, 9	1S. 1S.	14E. 14E.	XXIV p. 7
Ohio Diggins (Mackey)	21, 28	1N.	14E.	XIV p. 135; XXIV p. 7; XLV p. 53; B 23 p. 201; B 50 p. 248
Shell Ranch	17	1N.	14E.	B 23 p. 201; B 50 p. 248
Limestone				
Pacific Lime & Plaster Company* Claims: Ed Rudorff, Louis Ratte, Badgley Stone Entry	1	1N.	14E.	XIV p. 168; XVII p. 487; XXIV p. 47, 49; B 101 p. 270; AR '24 p. 230
U. S. Lime Products Co.	1 12	1N. 1N.	14E. 14E.	B 102 p. 177; B 103 p. 183; B 105 p. 183; B 109 p. 149; B 107 p. 180; B 110 p. 160; B 111 p. 281; B 112 p. 155; B 114 p. 150; B 116 p. 151; XIV p. 79; MR '29, 281
Magnesite				
Mackey (Maki, Peter)	6	1S.	14E.	
Maki, Peter (Mackey) Claims: Sunshine, Snow Drift	6	1S.	14E.	XXIV p. 50; XLV p. 81; B 79 p. 139
Monarch	6	1S.	14E.	XXIV p. 50; XLV p. 81; B 79 p. 139
White Rock Magnesite	6	1S.	14E.	XXIV p. 50; XLV p. 81; B 79 pp. 139, 140; MR '16, p. 397; MR '22, p. 47
Soapstone & Talc				
Brown, B.	36	2N.	14E.	XXIV p. 53
Finch, W. E.	36	2N.	14E.	XXIV p. 53
Hunter, A. D.	36	2N.	14E.	XXIV p. 53
Whitney, John L.		1N.	14E.	B 107 p. 194; B 109 p. 164

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